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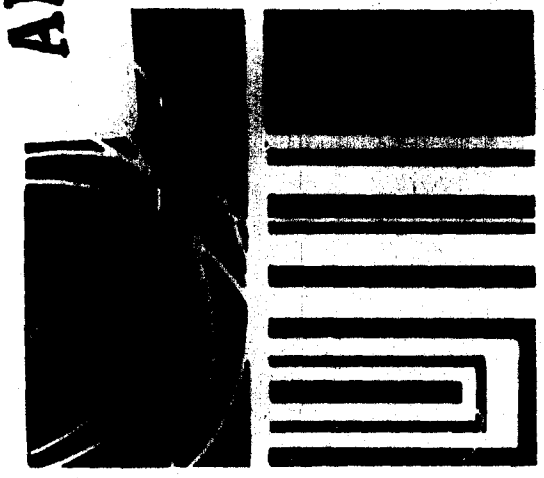

INDEPENDENT RESEARCH AND INDEPENDENT EXPLORATORY DEVELOPMENT

73

ANNUAL REPORT FY73

NAVAL ELECTRONICS LABORATORY CENTER
San Diego, California 92152

TECHNICAL DOCUMENT 267
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Foreword

The four programs chosen for highlights of the NELC IR/IED programs for FY73 are, at first glance, unrelated:

- The modeling of the ionosphere to predict coverage in the vlf spectrum
- Natural language interaction with a computer
- A device to provide easy, quick maneuvering and navigation information to the Naval officer conning a ship
- A method for using our communication channels more effectively by use of data compression.

But the dominant theme of harnessing the computer and its inherent capabilities to manage, assimilate, process, and manipulate large volumes of data is typical of the communications and command control efforts at NELC.

The use of a large computer to provide iterative processing of scientific data led to the understanding of a multivariable problem in atmospheric physics which is important to the Naval communicator.

The problem of the need to translate into machine language in order to communicate with a data base through a computer was addressed with the ultimate goal of making the information accessible to the ship commander for decision making in a tactical situation on a real-time basis.

State-of-the-art LSI techniques which have led to a computer-on-a-chip were exploited to build a special-purpose computer to solve a time-consuming, recurring problem for the ship's navigator.

Data compression via computer-implemented mathematical transforms achieved in the laboratory a significant reduction in the time required for transmitting image information for displays.

With regard to the management of the IR/IED program, modulation of the focal points of decision for program content, funding, and review is continuing in order to assure that the discretionary funds support the changing role of NELC in the Navy RDT&E community.

The FY74 IR/IED program resulted from the recommendation to the Technical Director of the newly formed IR/IED Program Council, a group formed of one member from each technical department, the Analysis Group, and the Planning Office, and chaired by the head of the Advanced Technology Office. Proposals originating from the technical staff were combined and grouped into larger, coherent efforts under designated program managers. In most cases there are participants from several divisions and more than one department.

This type of structure will lead to more visibility of the IR/IED work both within and without NELC and ease the transitions from IR to IED and from IED to advanced development. It will also ease the burden on the Technical Director of keeping knowledgeable of the work as it progresses. As seen in the listings of active projects on pages 95 and 96, this reorientation has reduced the number of individual projects from 47 to 12. The number of scientific and engineering subtasks has not decreased significantly and still covers the bulk of the mission responsibilities of NELC.

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Contents

Highlights of FY73

Lower Ionospheric Physics

C. H. Shellman

The global requirement for reliable strategic communications at vlf and elf has stimulated Navy interest in the lower ionosphere for over a decade. Hf ionosondes and rocket soundings provide little information, and other methods are required to provide the needed data. NELC ascertains the electrical characteristics of the D-region from the reflection characteristics of vlf and elf waves, and has recently developed a profile inversion technique using the reflection data which promises to provide the pertinent atmospheric information on a global basis economically.

The NELC technique will be employed in a joint Navy-Air Force program sponsored by the Defense Communications Agency to determine the characteristics of the lower ionosphere and in another program sponsored by the Defense Nuclear Agency to determine the response of the lower ionosphere to particle precipitation during auroral events.

A rational and consistent physical, chemical, and electrical description of the lower ionosphere has been the objective of Navy and other Government sponsored research for more than a decade. The principal Navy interest stems from the global requirement for reliable strategic communications at very low and extremely low radio frequencies (vlf and elf). Numerical methods are available for accurately calculating vlf and elf system performance capabilities as functions of design parameters if the height distributions of electron and ion densities and their respective collision frequencies in the lower ionosphere are known. Although much has been learned over the years, a reliable ionosphere model which takes into account diurnal, seasonal, latitudinal, meteorological, and solar-related variabilities has remained elusive. Researchers have been frustrated in their efforts by an inadequate data base.

The nature of the lower ionosphere, the D-region, has placed the greatest barrier against the acquisition of plentiful and reliable data. Because of low electron and high neutral-particle densities, the usual hf ionosondes provide no data for the D-region. For the same reason the data from rocket soundings, sporadic at best and often suspect, provide little detail in the lower D-region. These difficulties have compelled researchers to seek other ways to obtain the needed data. NELC has followed an approach which utilizes the reflection characteristics of vlf and elf waves to ascertain the electrical characteristics of the D-region. A recently completed profile inversion technique which uses the reflection data appears to provide the long awaited means for obtaining the pertinent ionospheric information on a global basis economically. The method makes use of relatively easy to obtain radio measurements, each of which is some function of the reflection coefficients of the lower ionosphere. It also uses a numerical technique which calculates the reflection coefficients of the lower ionosphere using full-wave solutions if given the charged particle and collision frequency distributions.

A trial-and-error approach used by a number of workers, including some at NELC, was simply to try many electron-density and collision-frequency profiles in hopes that one would yield computed reflection coefficients in agreement with experimental data. Each new trial required considerable computer time, and there was no guarantee that the true profile would ever be found. It eventually became clear that, although the basics of the approach were sound, a less heuristic profile search technique was essential.

Near the end of FY71 a mathematical technique was devised under the Independent Research Program which determined the *rate of change* of reflection coefficients with respect to changes at each point in the profile. Since this computation was fast, it opened up a whole new range of possibilities for economically finding the true profiles from the data. There were a number of numerical difficulties with nonlinearity and truncation error in the full-wave solutions, but these problems were resolved in late FY72. The approach finally selected was to use a smoothing function which is incrementally "relaxed" as detail is allowed to develop in the profile.

With the introduction of the concept of profile smoothing to accommodate experimental uncertainty and a finite data sample, some measure of the error width and height resolution of the deduced profile was needed to satisfy questions of "uniqueness" of the profile found to fit the data. One of the major accomplishments achieved under the FY73 Independent Research Program was the formulation of an

error analysis consistent with the smoothing scheme used in the profile search. A second accomplishment was a physically meaningful definition of profile resolution. Figure 1 illustrates the concept of resolution as an indicator of the amount of profile smoothing done as a function of height. A third accomplishment was to extend the error analysis to the case in which an exponential collision-frequency profile, as well as the electron-density profile, is found from experimental data. In summary, the inversion computations produce profiles of electron density, N_e, and electron-neutral particle collision frequency, ν, a measure of the profile error or uncertainty, $\delta \log N_e$, resulting from experimental uncertainties, and a measure of the height resolution of the profile. The experimental data consist of measures of ionospheric reflection coefficients at a number of radio frequencies at a single angle of incidence (as obtained by special vlf sounders) or vlf field strengths obtained at a number of distances along a great-circle path from a regular communications transmitter.

Considerable effort was expended in the last half of FY73 verifying the accuracy of the inversion method. Other researchers had often asked: "Have you ever tested your inversion scheme with simulated data to see if the derived profile matches the profile used to obtain the simulated data?" A unique opportunity for such a test came in November, 1972, when J. S. Belrose, of the Communications Research Center, Ottawa, Canada, presented NELC with a challenge. He proposed that he and a colleague, B. Segal, would supply NELC with simulated reflection coefficient data computed from a profile known only to them. NELC would "invert" these data to derive an electron-density profile which would be sent to them. The original and derived profiles would be compared publicly at the COSPAR-URSI-IAGA Symposium on Methods of Measurements and Results of Lower Ionosphere Structure, Konstanz, West Germany, in May. A similar challenge had previously been presented to the Soviet worker, P. Y. Krasnushkin. In the year or so that Krasnushkin had had the data, he had not responded with a derived profile, according to Belrose.

Belrose furnished curves of reflection coefficients from which data points were read with an accuracy of 10% to 30%. The reading error was interpreted as experimental error; thus, the data were ideally suited for testing both the profile inversion technique and the error analysis. Figure 2 shows the results of the test. It is of interest to note that the profiles are nearly identical in the region predicted by the error analysis curves.

A more stringent second test was made to rule out

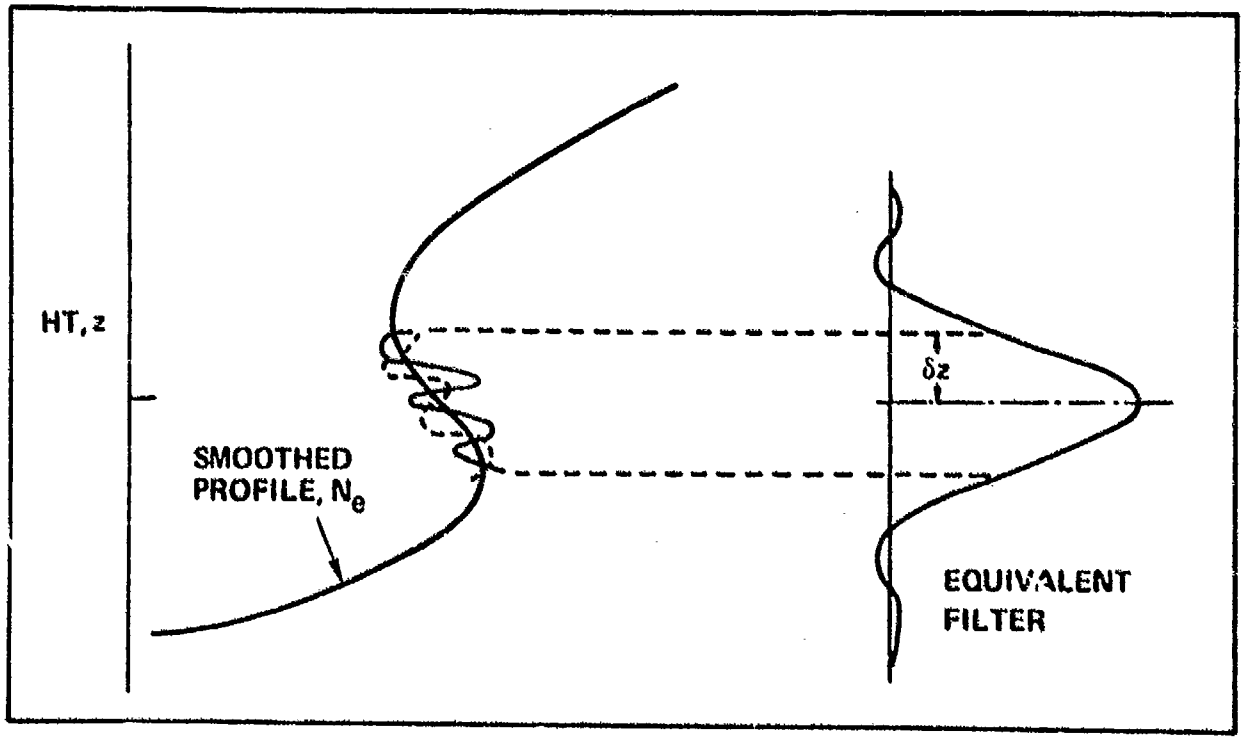

Figure 1. The equivalent smoothing filter. Detail in the profile smaller than the width of the filter cannot be determined uniquely, hence is "smoothed out." The width of the (optimum) filter is a function of height and may be very narrow in height regions associated with reflection.

the element of luck. In this test both the electron-density profile and the collision-frequency profile were to be deduced. Figure 3 shows the test and derived electron-density and collision-frequency profiles as well as the error analysis and resolution curves. The remarkable agreement is evident from the curves. Belrose presented these results at the Konstanz meeting and indicated that the long awaited solution to the profile inversion problem had been found.

Further tests nave been made at NELC to determine the performance of the inversion method when small-scale roughness in the electron-density profile is present. Reflection coefficients corresponding to the "Mechtly and Smith" (fig 4) profile were used in the inversion scheme to determine whether a smoothed version of the profile could be obtained from the synthetic data. Figure 4 shows how well the original and derived profiles agree even though the reflection coefficients were found to be sensitive to roughness in the data profile.

The preceding examples illustrate the ionospheric profiles deduced from reflection coefficients for a number of radio frequencies. During FY73 work was completed in implementing a method for determining the ionosphere structure from long-path single-frequency vlf data. The data are field strengths within the earth-ionosphere waveguide at a number of positions. The profile adjustments (fig 5) require an intermediate step in the computations, the calculation of waveguide mode parameters. Tests of the method have been carried out with both simulated and measured data. Figure 6 shows simulated field strengths as a function of distance compared with those derived by the profile inversion calculations.

The profile inversion technique has potential for other remote measurement applications. The basic requirement is that the mechanism of interaction between the probing wave (electromagnetic, acoustic, seismic, etc.) and the medium be understood and that a set of measures of the interaction be made. The profile inversion technique will then provide a description of the propagation medium. Applications of the method for remote probing of the troposphere and for inversion of ionospheric data derived from wave interaction experiments are under study.

The profile inversion methods have reached the stage of development under the Independent Research

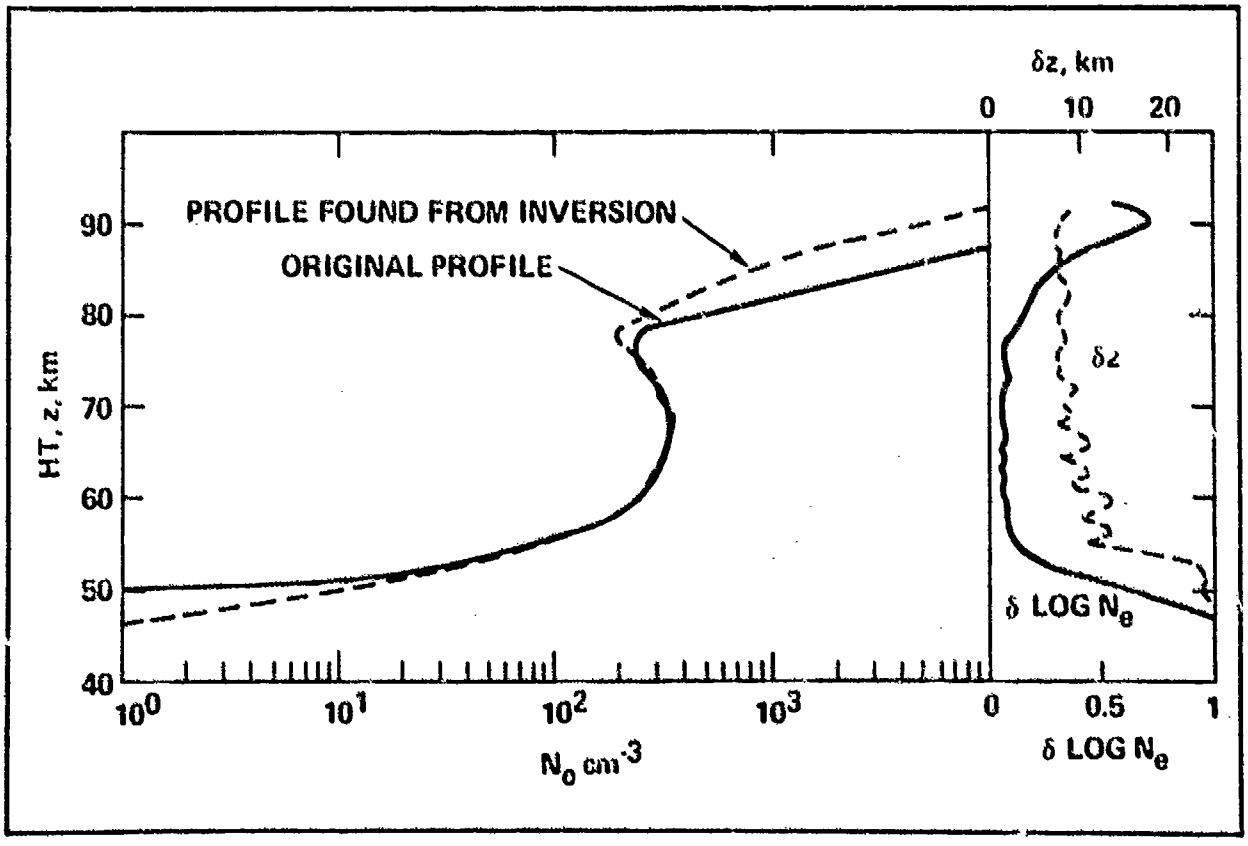

Figure 2. Comparison of Dr. Belrose' original profile with profile deduced from reflection coefficients at 8 frequencies, 3 to 20 kHz.

Program at which they are ready to be used for practical applications. During FY74 and FY75 a joint Navy-Air Force program sponsored by the Defense Communications Agency will make measurements of vlf propagation from both regular communications transmitters and special transmitters over both temperate and arctic regions. The profile inversion technique will be used to determine the characteristics of the lower ionosphere from the measurements. Another program, responsive to Navy strategic communications requirements and sponsored by the Defense Nuclear Agency, will utilize data obtained by multiple-frequency near-vertical-incidence vlf ionospheric sounders in the auroral zone. The profile inversion technique will be used to determine the response of the lower ionosphere to particle precipitation during auroral events.

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(NELC Z135)

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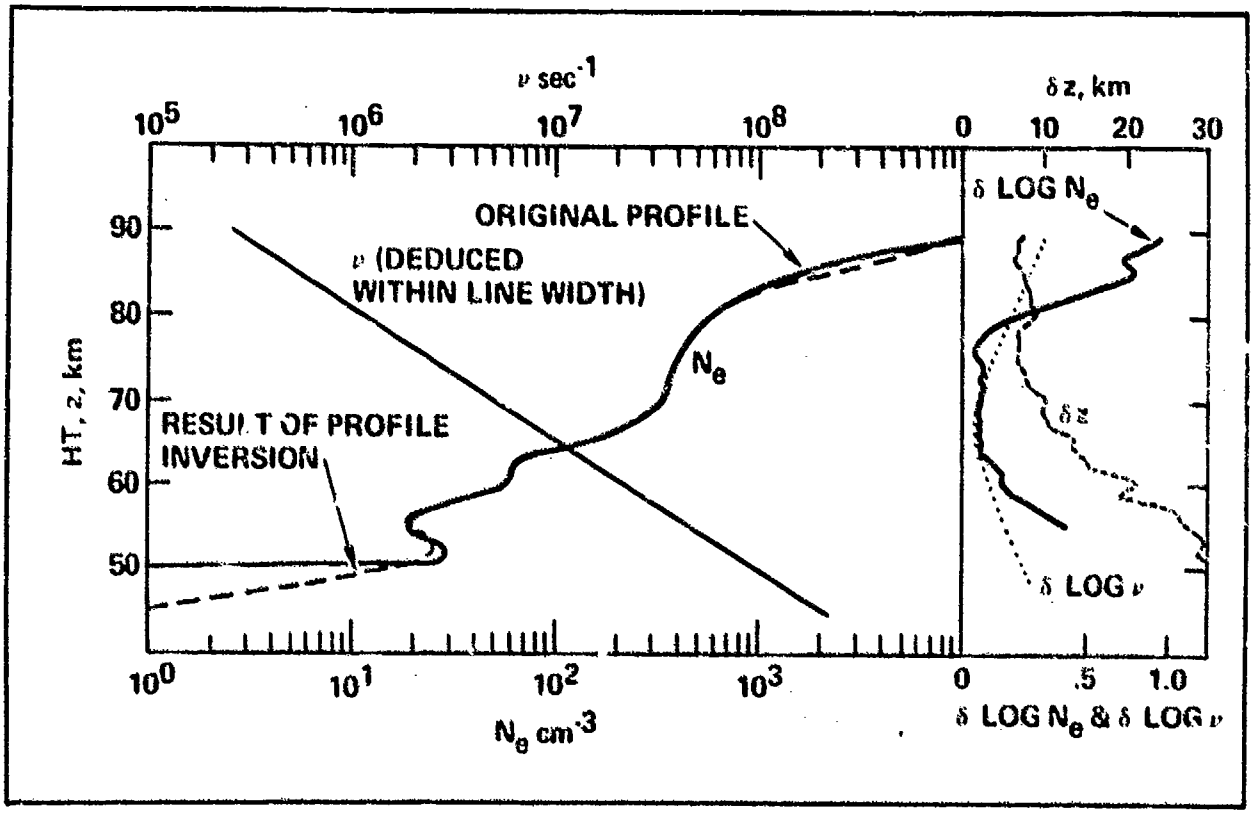

Figure 3. Comparison of Dr. Belrose' second profile with profile deduced from reflection coefficients at 10 frequencies, 10 to 30 kHz.

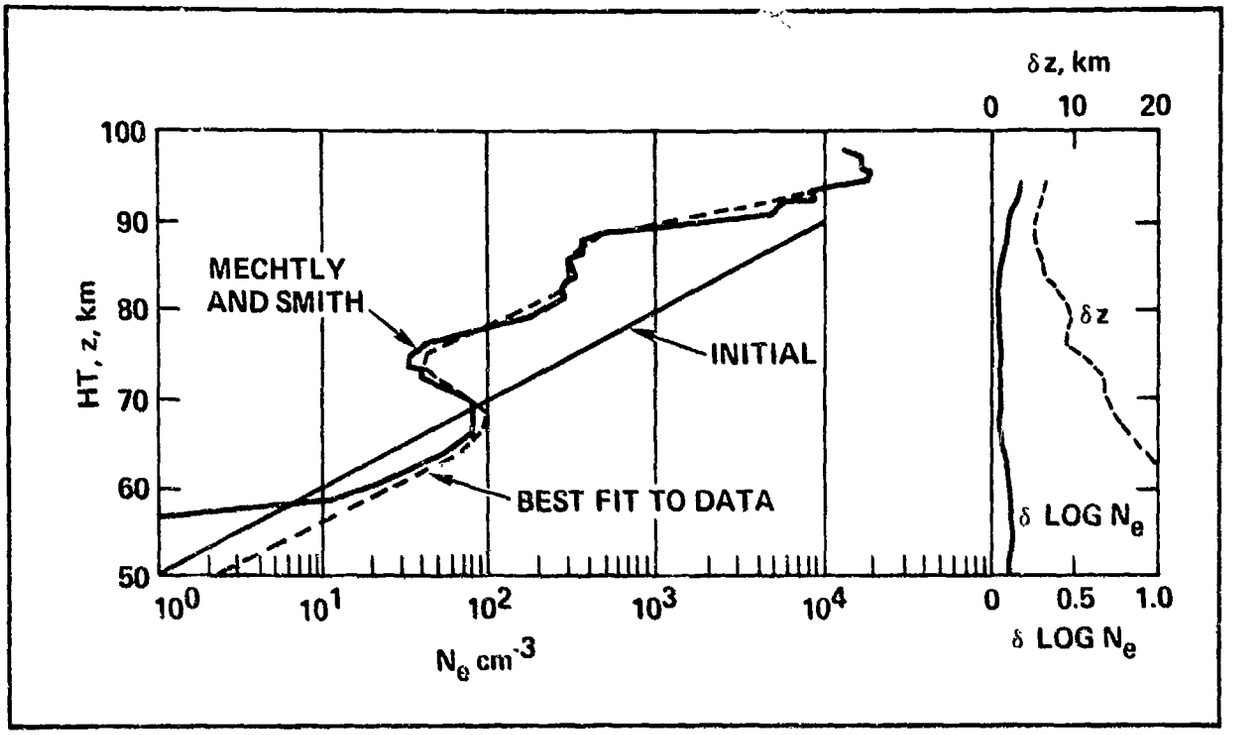

Figure 4. Comparison of data (Mechtly and Smith) and deduced (best fit) profiles illustrating smoothing capability of the inversion scheme.

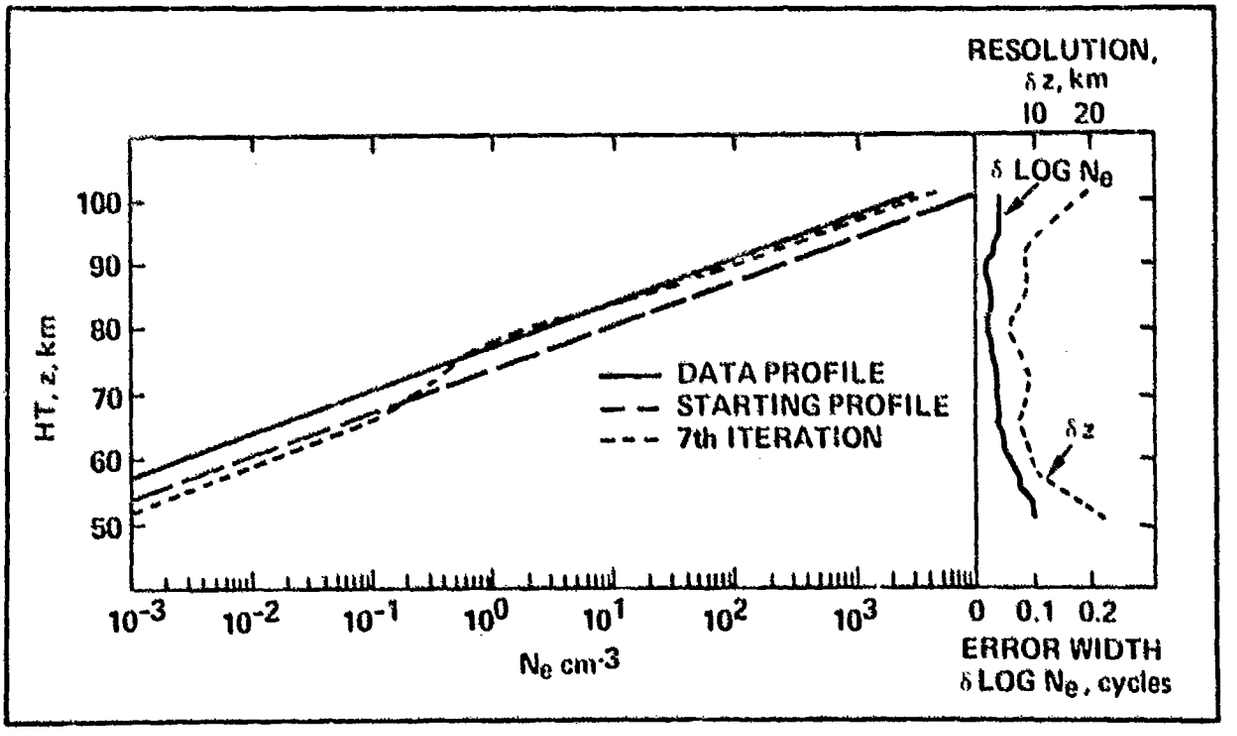

Figure 5. Data profile and starting and best-fit (seventh iteration) profiles for inversion using simulated vlf waveguide data.

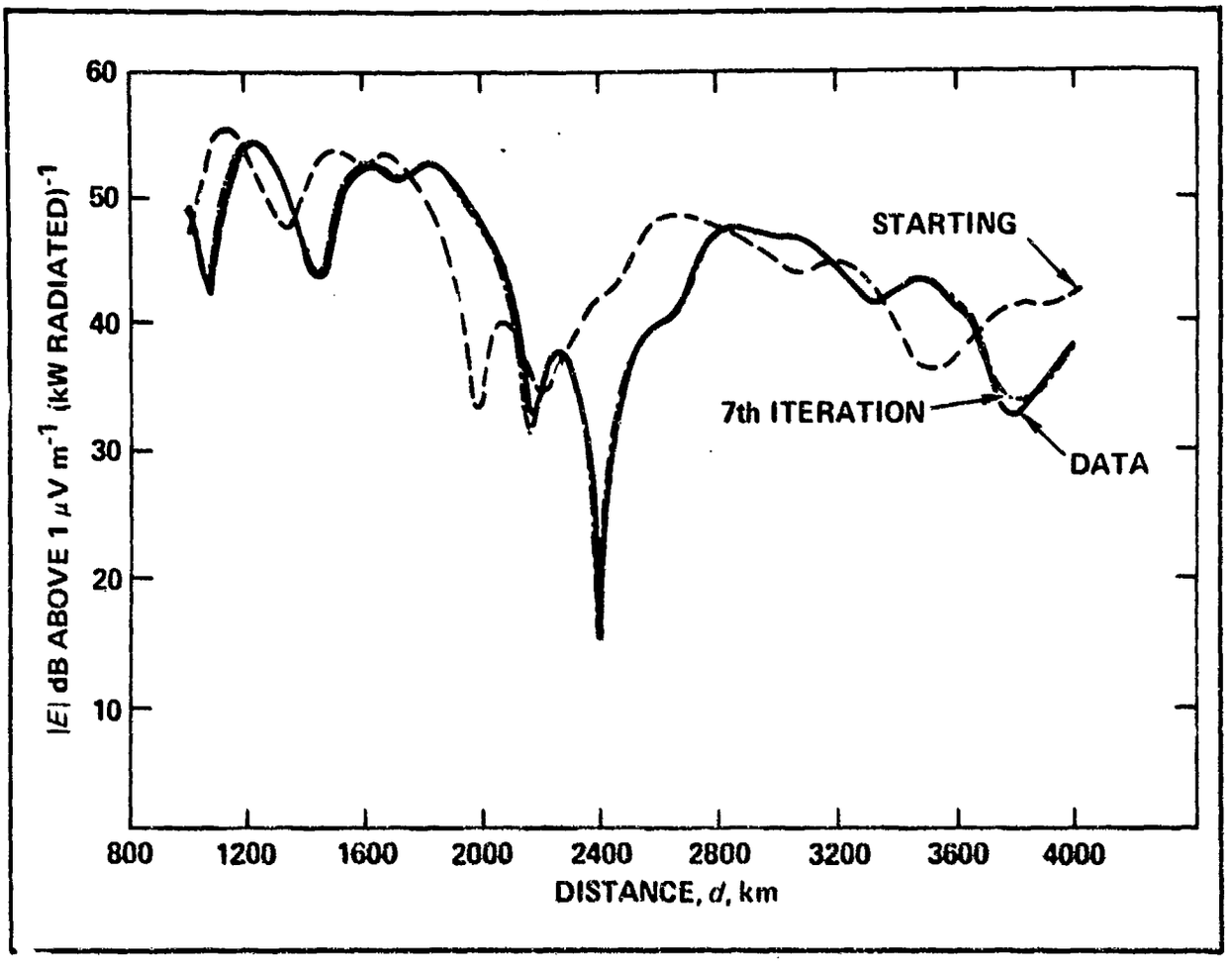

Figure 6. Field strength vs distance for profile inversion using simulated vlf waveguide data.

Natural Language Development

At present users of Navy information storage and retrieval systems are given very little chance to impact software development for their systems prior to delivery. The result is systems with stylized communication interfaces which must be understood. Consequently, long training periods ensue before actual usage can begin. As the available Navy manpower becomes more limited, the need for machines to accommodate users of less and less experience becomes more acute. Little time and money will be available for extended training in complex and sophisticated computer systems. The Natural Language Development project is seeking to close the gap between the inexperienced user and Navy command control computer systems.

The circumstances under which command control computers are used by Navy personnel—particularly in combat—make it essential for communication between man and machine to be as easy and natural as possible. The technology has reached the point at which the machine can be addressed in English, but the English as yet must be structured in an arbitrary fashion according to exacting rules of grammar. This requirement is a barrier between man and machine in times of stress, when language tends to become informal.

The Natural Language Development project in FY73 focused on the problem of machine understanding of colloquial English. An experimental concept has been developed at NELC for computer processing of incomplete sentences and is being tested on the Center's IBM 360-65.

A study of needs and expectations of such users was undertaken in FY72 and the early part of FY73. The study showed that these users, when exposed to a fairly natural interface with the computer, become relaxed and colloquial in dialogue with the machine. They also need considerable system prompting to explain the latter's level of understanding. The results were reported in detail at the Office of Naval Research Conference on Text Processing and Scientific Research in November 1972, and at the American Society of Naval Engineers Annual Conference in April 1973.

During FY73, this research has focused on the problem of machine understanding of colloquial English. The aforementioned presentations describe an experimental concept for computer processing of incomplete and poor sentence structure. The concept, as diagrammed in figure 1, is now being tested on the Center's IBM 360-65.

Traditionally, machine understanding of natural language, such as English, is done by parsing a sentence (diagramming it automatically) according to stringent grammatical rules. Once a grouping (or parsing tree) of the sentence is completed—there may be several good ones—an interpretation of it is given within the context of the semantic routines which are coded into the computer. In the context of today's data management systems, the computer might take the form of a module for searching data and retrieving certain categories or of a module for updating data.

Some major problems exist with this traditional approach. One is the inflexibility of the grammars used. The rules are normally based on a linguist's interpretation of standard English as it should be, not as it is. For input in colloquial English, therefore, this approach requires treatment as a series of exceptions. A consistent approach to the understanding of the sentence would be possible only for input in ideal or "standard" English.

Figure 1 depends upon a grammar based on usage of English which was originally proposed by C. Fries in *The Structure of English*, 1952. Structure enhancement was the result of this year's research by NELC into how to process poor sentence structure using Fries' grammar as a base.

Specifically, structure enhancement is based on the assumption that only pertinent information is conveyed in discourse in which some context is assumed. For instance, if a user of a data base on census data asks, "What is the population of San Francisco?" then "of Los Angeles?" then "San Diego?" the system will enhance the latter two queries so that they can have potential meaning. In the case "of Los Angeles?" a leveling function word *and* is appended to the previous query. If the leveling "makes sense" in terms of the data summary, the question can be answered. In the last query "San Diego?" the function word *of* is first tried. Forms of the verb *to be* are used for enhancement, as are the question-signaling words *what, why, who,* etc., and the function word *there*. P. Beckmann, who recently published *The Structure of Language—A New Approach*, discusses the role of function words as "check words" when likening language structure to information theory. His discussion gives considerable credence to the proposal that function

words are normally necessary to prevent ambiguity, not to convey information. Hence, it also supports the belief that structure enhancement will give new insight into the processing of colloquial English.

Structure enhancement depends heavily on rapid data access. Thus, a need surfaces to find a summarized representation which can help minimize the number of accesses of raw data. This summary, in the experimental concept, takes the form of description lists. These are taken from parsed English sentences and, in the machine, can point to arrays of information (or perhaps more complex data structures) and elementary information processes to be performed. For example, consider the parsing or sentence grouping *(the sailor (sighted (a submarine)))*. The one-element list *sighted* could point to a two-dimensional array which contains the data elements *sailor* and *submarine* as one entry. *Sighted* would also point to elementary procedures for retrieving and updating that array. An exploration of this problem of data representation is contained in the Navy Postgraduate School Report *Data Structures for Question Answering Systems*, completed under this research.

Future research will continue concept testing. Inclusion of procedural data into the concept will also be considered.

The Computer Sciences Department of the Naval Electronics Laboratory Center is sponsoring continuing development of this research.

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(NELC Z166)

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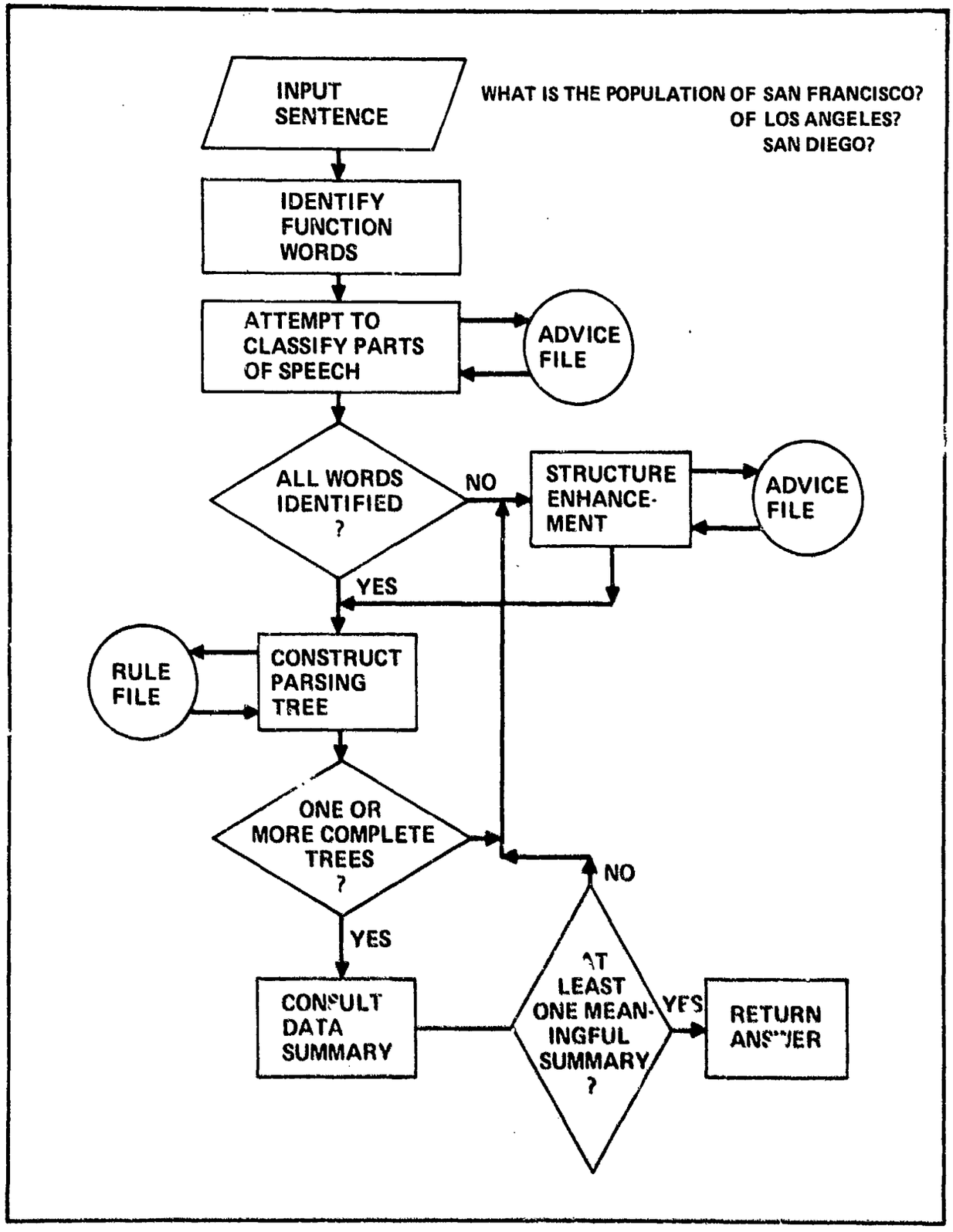

Figure 1. "Structure enhancement" enables the computer to function even when the input is colloquial and fragmentary. The operator questions the computer as he would another human—sometimes in sentences, sometimes in bits of sentences. As a human would, the computer expands the bits of sentences into meaningful questions by fitting them into the preceding dialogue as appropriate. In the example, stimulated by "San Diego?" the computer responds with its population.

Small Ship Electronics–Closest-Point-of-Approach Calculator

A. Roth

A calculator developed by NELC as a demonstration of computer-on-a-chip technology accepts radar position data inserted manually via a keyboard and computes closest-point-of-approach (CPA) parameters—almost instantly—for up to five target ships. The final package may be as small as 5 by 6 by 7 inches—yet invaluable in collision avoidance.

The technique most commonly used by the Navy for collision avoidance is to manually plot the relative motion between one's own ship and the target ship on a plotting board from radar-derived data. Range, bearing, and time of CPA, as well as target ship speed and course, can be derived geometrically from the plot through the use of a scale, dividers, and parallel rule.

This method of CPA determination is time-consuming and error-prone, depending to a large extent on conditions and the skill and experience of the operators. A need exists for a simple, low-cost method—rapid, accurate, and independent of highly skilled and trained personnel.

NELC attacked the problem by developing a small Closest-Point-of-Approach (CPA) calculator which can rapidly and accurately compute the five desired CPA parameters for up to five ships. The heart of the calculator is the central processing unit, a small but powerful MOS LSI computer-on-a-chip which was purchased off the shelf from North American Rockwell Microelectronics Co. The single card assembly can perform 32 functions, 24 of which are used in the calculator. NELC worked out the five equations required for the solution of the problem and developed the algorithms for the unambiguous solution of the equations.

The programmed portion of the calculator consists of a hardwired microprocessor using field-programmable ROMs (Read Only Memories) programmed to generate all the instructions required to implement the algorithms—approximately 600 of them.

The calculator accepts manually inserted radar position data (via a keyboard) for up to five target ships, time of measurement, and own ship's course and speed. From these data, the calculator can almost instantly compute any or all five CPA parameters for each target ship.

A breadboard model of the calculator was successfully tested aboard the carrier USS TICONDEROGA during a recent 1-week trial period. The calculator proved a valuable asset to the non-NTDS Combat Information Center.

The calculator was developed from available off-the-shelf components as a demonstration of today's computer-on-a-chip technology. Follow-on effort could result in a compact MOS LSI package approximately 5 by 6 by 7 inches in size capable of automatic target acquisition and computation, including "course to avoid" determination in the event of an impending dangerous situation.

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(NELC Z253)

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Source Encoding for Data Compression

D.C. McCall

Data compression of three to one is attainable in an image transmission system which transmits a coded version of a "transformed" image rather than the image itself. The transformed image is a version of the image which has been simplified geometrically without loss of information. The number of bits transmitted is reduced by two thirds. The reconstructed image is of good resolution, and the resolution can be controlled to suit requirements.

NELC is evaluating two transforms for use in such a system – the Walsh and the slant. A Digital Frame Capture Unit (DFCU) digitizes and stores the images on tape. Transform encoding and decoding are simulated by a digital computer program, and the results are displayed by the DFCU.

The techniques and equipment developed here may be applied in memory size reduction in bulk storage systems, color encoding, pattern recognition, image enhancement and restoration, and graphic displays.

Transform source encoding is a technique which permits transmitting a coded version of a transformation (for example, Fourier or Walsh) of a digitized image rather than the image itself. The motivation for using this technique is that coding the spectral components of pictorial sources provides higher coding efficiency coupled with computational simplicity. Data compression ratios of at least three to one with adequate image resolution should be achieved. Increased noise immunity is also obtained with transform techniques. The Walsh transform, an expansion in terms of rectangular waveforms, and the slant transform, an expansion by sawtooth waveforms, are being evaluated for implementation in an image transmission system.

To evaluate these candidate methods, equipment to digitize images for processing and to display processed images was necessary. Television was selected as the working medium and a Digital Frame Capture Unit (DFCU) was acquired. This equipment is designed to accept TV images, convert them to digital format, and store them for subsequent transfer to digital tape. The DFCU will also accept data from the tape for display. Thus, by use of the DFCU, an image can be digitized and stored on magnetic tape for processing on a general-purpose digital computer. The processing we refer to is the simulation of a transform encoder and decoder by a digital computer program. After processing, the results of the simulation can be displayed via the DFCU.

The DFCU shown in figure 1 was built to NELC specifications and is functionally represented in the block diagram in figure 2. The video input can be any standard video source such as a camera or video tape recorder. The A/D converter samples the video signal at 12 MHz. This rate satisfies the Nyquist criteria for reproducing 5 MHz and maintains the 4-to-3 width-to-height ratio in the digitized image. After one frame is sampled it is stored in the solid-state memory. Storage capacity of the memory, which uses MOS shift registers, is 1.8 megabits. The captured image is now represented in the memory by an array of numbers with 485 rows and 640 columns, with each entry in the range from 0 to 63; that is, six-bit resolution is provided. The entries are called picture elements or pixels. Communication into and out of memory is provided via the digital tape transport. This unit writes nine-track tapes which are IBM compatible. A maximum of 20 frames can be stored on an 8-inch reel of tape. The contents of the memory are displayed (after D/A conversion) on a standard 525-line TV monitor. Of the 525 lines, 40 are lost to blanking, thus giving 485 active lines for processing. Although the DFCU initially was designed for data compression studies, it can be used in any work requiring digitization of images or display of digitized images. An IMAGE INVERT switch allows a negative input to be displayed as a positive and vice versa. Digitization levels of 1 through 6 bits can be selected by the BIT PRECISION switch.

A typical image transmission system is illustrated in figure 3. The image reader and image display are simulated by the DFCU, with the remainder simulated by software. The data compression calculation is performed in two stages – a linear transformation, T, followed by a tapered quantization, Q, of each transform coefficient. The digitized image, an array of numbers, is organized into smaller blocks for ease of processing and to take advantage of the correlation between adjacent pixels. An optimum transform exists which produces uncorrelated transform (spectral) elements that can be independently quantized and transmitted. Since this transform is impractical to implement, we turn to suboptimal transforms, such as the Walsh and slant, which produce nearly uncorrelated spectral coefficients. Treating the spectra of Walsh and slant transforms as if they were uncorrelated has worked well [ref 1].

A discrete linear transformation is implemented through matrix multiplication. When a block of pixels is transformed, the entries in the upper left corner of the transformed matrix have the largest magnitudes. These terms are analogous to the low-frequency terms in the Fourier theory. The remaining entries have low magnitude. Tapered quantization allocates more bits to coefficients of large magnitude and either eliminates those of smaller magnitude or allocates fewer bits to them. Figure 4 illustrates a bit distribution for a 4-by-4 block of pixels. Thus, encoding the transformed coefficients in this example has reduced the total number of bits transmitted by a factor of 3. Rather than the spatial elements, resolved to 6 bits, for a total of 96 bits, the encoded version of the transformations is transmitted for a total of 32 bits, or an average of two bits per picture element. At the receiver, decoding and inverse transforming take place to regenerate the image.

Figure 5 presents an image before transmission over the simulated system using the Walsh transform and as received. In this example six transform coefficients were set to zero and the remainder quantized to the full six bits. As can be seen from figure 5, no loss of fidelity is caused by deleting these coefficients. Picture quality is extremely sensitive to the efficiency with which the bits are used to code the coefficients. By judicious choice of quantization levels, good-quality pictures can be transmitted at two bits per picture element [ref 2]. Other researchers report averages of 1.5 bits per pixel using the slant transform [ref 3]. Walsh transforms can be implemented by addition and subtraction of the data vector while multiplication is required for the slant transform.

The nature of transform source encoding allows exact control of the average number of bits per pixel. In other words, the exact compression ratio is known. With this control, a tradeoff can be performed between compression ratio and image resolution. Since images are intended for humans, this evaluation is necessarily subjective. In addition to compression, increased noise immunity is afforded by these techniques. Since each transform coefficient contains information about every element in the block, any corruption of these elements is averaged over the entire block. Furthermore, the block organization of the digitized image causes this noise to appear as speckling rather than as the more distracting streaking that can occur with other techniques.

The equipment and techniques developed in this project have a wide variety of applications. Immediate plans include frame-to-frame compression for memory size reduction in bulk storage applications and color encoding. Possible long-range uses of the equipment are pattern recognition experiments, biomedical applications, image enhancement and restoration, and graphic displays.

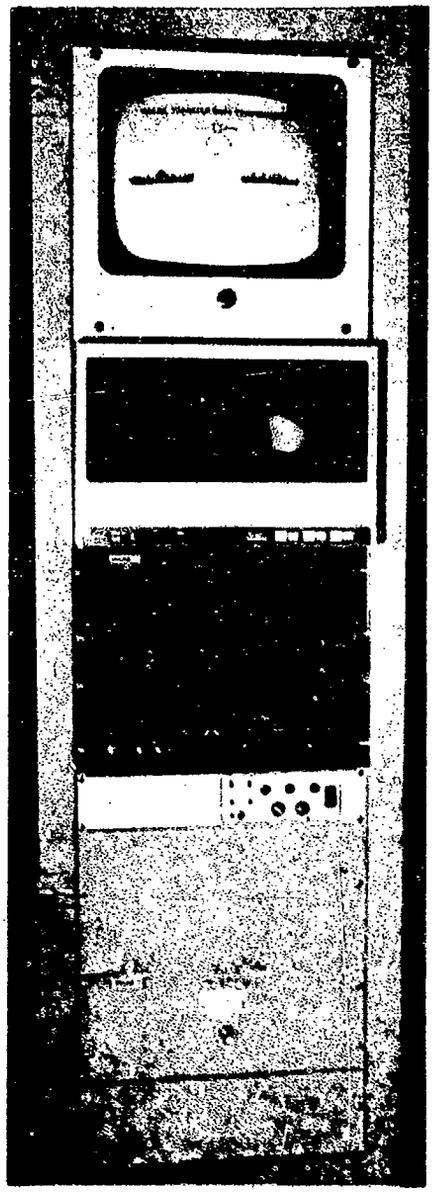

Figure 1. Digital frame capture unit (DFCU).

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(NELC Z257)

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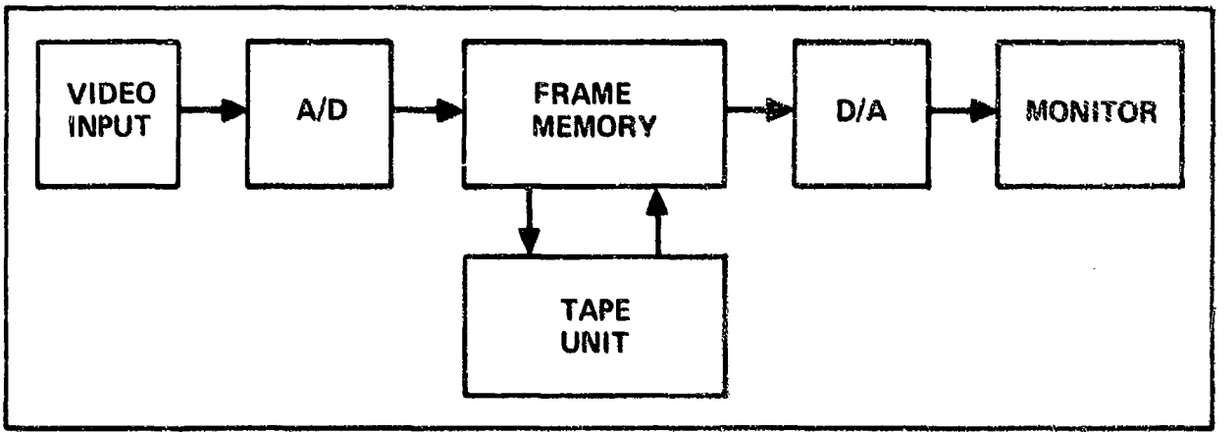


Figure 2. Block diagram, DFCU.

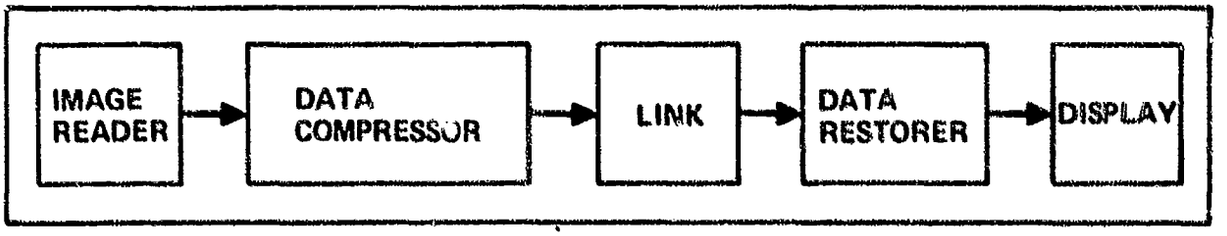


Figure 3. Image transmission system.

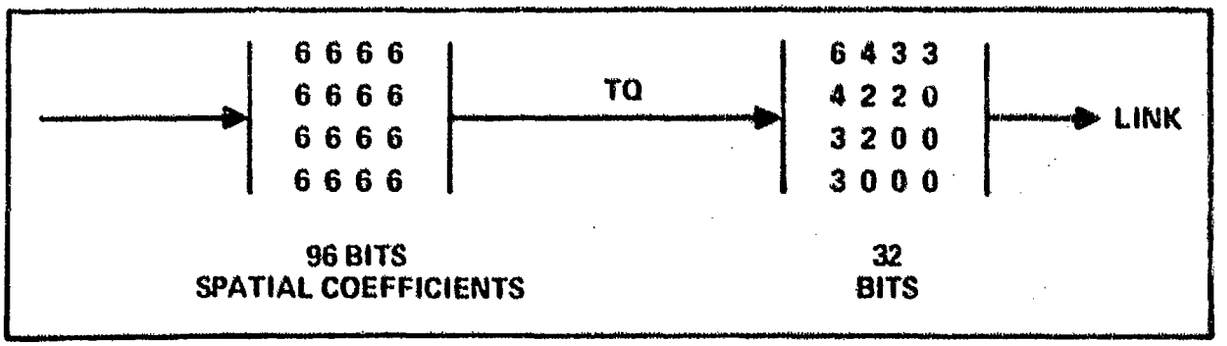
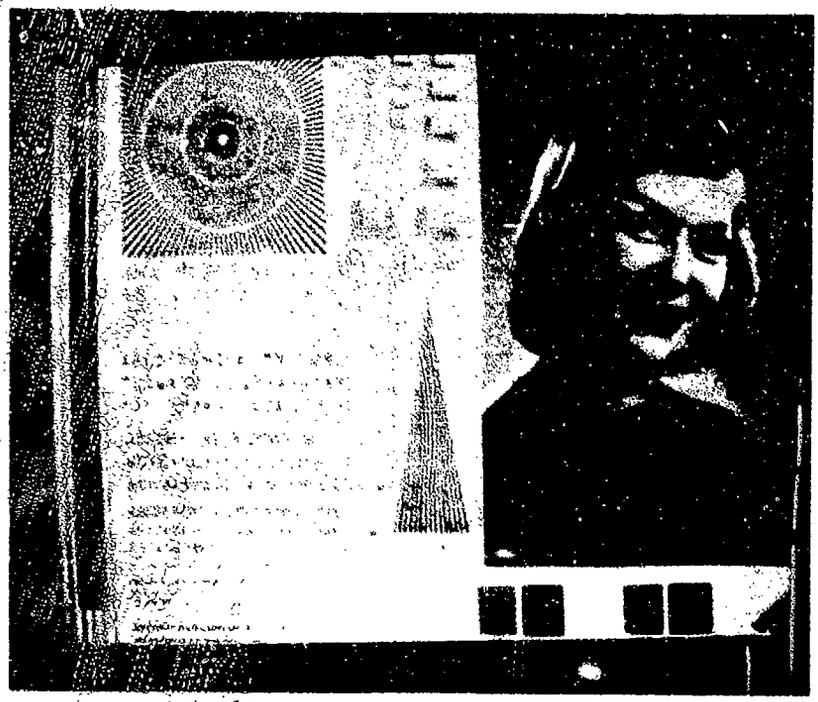
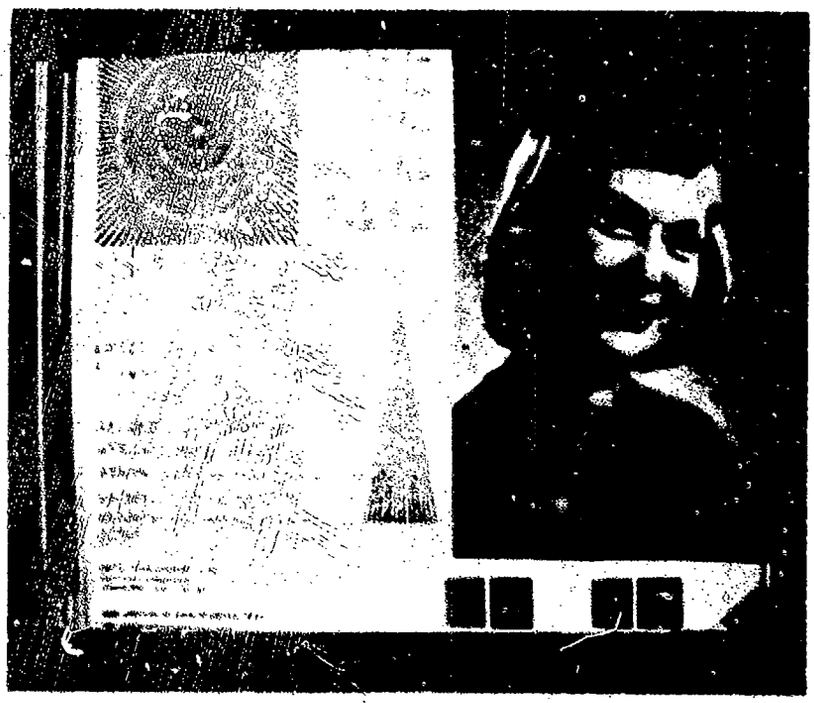


Figure 4. Data compressor.



BEFORE



AFTER

Figure 5. Original and reconstructed photographs.

Sponsored Projects Based on IR/IED-Initiated Work

(Only projects not listed in earlier reports)

Funding	NELC No.	Title	Based on
OPTICAL TECHNOLOGY			
1. 61101F AF CRL	F218	Fiber Optics Radiation Effects	ZFXX.512.001 (NELC Z237)
2. 62755N XF54 545 022	F219	Fiber Optic TV System	ZF61.212.001 (NELC Z246)
3. 62755N WF54 545 603	F220	Fiber Optics Data Bus Study	ZF61.212.001 (NELC Z246)
4. 62755N WF53 533 602	F221	Fiber Optics–NEMP	ZF61.212.001 (NELC Z246)
5. 62755N RF54 545 102	F222	Fiber Optics Data Bus System	ZF61.212.001 (NELC Z246)
6. 62703E ARPA	T304	Fiber Optics Evaluation	ZF61.212.001 (NELC Z267)
7. 62755N WF53 533 602	F223	Fiber Optics Avionics Signal Transfer	ZF61.212.001 (NELC Z246)
8. 62755N XF54 545 022		Fiber Optics Technology Development Program	ZF61.212.001 (NELC Z246) ZF61.212.001 (NELC Z261)
9. 63534N S4629	G308	Surface Effect Ship Infrared Signature Program	ZFXX.112.001 (NELC Z221)
10. 62751N WF11 121 710	F224	Fiber Optic Sonobuoy System	ZF61.212.001 (NELC Z261)
ELECTROMAGNETIC PROPAGATION			
Kirtland AFB	M215	Airborne VLF Propagation	ZR021.01 (NELC Z135)
DCA	M216	DCA VLF/LF Propagation	ZR021.01 (NELC Z135)
O&MN NAVSUP	M217	Consultation Studies in Radiowave Propagation	ZR021.01 (NELC Z135)
DNA	M218	Auroral Zone D-Region Sounding	ZR021.01 (NELC Z135)
CONTROL TECHNOLOGY			
O&MN NWL	N441	Mk 68 GFCS Update Program Support	ZF61.512.001 (Z239)
MICROELECTRONICS			
62755N XF54 545 019	R137	Integrated Circuit Reliability and Manufacturing Science (ICRMS)	ZFXX.512.001 (NELC Z229) ZF61.512.001 (NELC Z262)

Applications Resulting from Past IR/IED Projects

TIME-COMPRESSED DISPLAY SYSTEM

TICODS was started under Independent Exploratory Development task ZFXX.512.001 (NELC Z214) in 1966. Since 1971 it has been funded by NAVSHIPS on 78012N, 62721N SF23.337.004, and 64518N S31-31 (NELC N437). An Engineering Development Model has been successfully tested at NELC and in USS ENGLAND (DLG 22). A contract has been awarded for service test models for OPEVAL.

VISUAL ELECTROPHYSIOLOGICAL RECORDING SYSTEM (VERS)

VERS was installed at Naval Hospital San Diego in late FY73 to be used by the Ophthalmology Department to study certain macular diseases and other conditions affecting visual efficiency. Funded by BUMED 63706N M4305 and NHSD (NELC S101), it derived from basic studies on the visual evoked cortical potential and experimental techniques which were developed on ZR011.01.01 (NELC Z150) begun in 1966.

MINICONTROLLER

The minicontroller, a modularized digital controller for analog power drives, was developed under ZF61.212.001 (NELC Z239) during FY71-73. Two production models funded from O&MN (NELC N441), will be delivered during the first quarter of FY74 to the Naval Weapons Laboratory for the proposed updated Mk 68 Gun Fire Control System. The minicontroller is also being used to control a miniature three-axis K_a-band satellite communication antenna, funded by 11403N X15-11, under development at NELC for the SURVSATCOM project.

SUBMARINE-TO-AIRCRAFT OPTICAL COMMUNICATIONS (SAOCS)

The SAOCS project, 64520N S3203 (NELC B214), could be confidently undertaken within its time frame only by scientists and engineers whose expertise in laser technology had been previously developed on the Independent Research and Independent Exploratory Development programs. The final Advanced Development Model will be completed in June 1974. Theoretical calculations have been verified by feasibility tests and other experiments. Details are classified.

FIBER OPTICS TECHNOLOGY DEVELOPMENT PROGRAM

In FY71 fiber optic cables showed promise for application in Navy systems. That year two projects were funded from Independent Exploratory Development funds: a 3-year one, ZFXX.212.001, Optical Data Multiplexing (NELC Z242), and ZFXX.512.001, Optical Components for Information Transfer (NELC Z237). In FY72 additional ZF61.212.001 funds were used for Fiber Optic Communication (NELC Z246), and in FY73 work was done in Fiber Optics Emitter/Detector Evaluation (NELC Z621) and Fiber Optics Engineering (Z267). As a result, NELC has become the Navy's principal investigator and lead laboratory for the DoD Fiber Optics Technology Development Program.

This program, which will be initiated during FY74, is to be a mixture of funding category efforts (6.1, 6.2, and 6.3) designed to optimize the evolution of fiber optics from the military user's point of view. Year-to-year technological and economic objects and tangible fallouts for military systems are to be the major guidelines. Initially it will be funded by NAVELEX and NAVAIR for approximately $850k, and it is planned that it will continue through FY75 and 76 with over $1M each year.

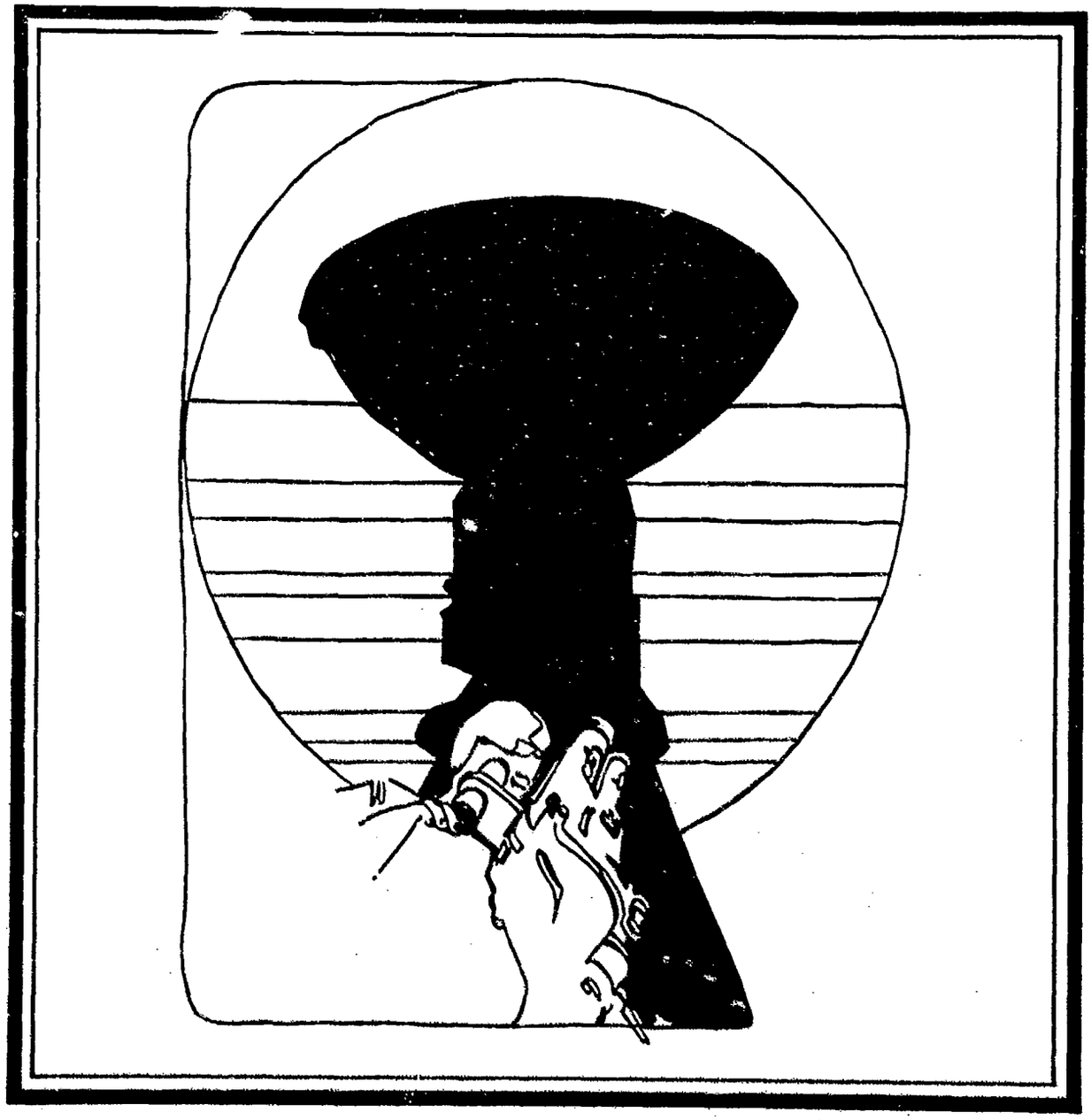
In FY72 and 73 sponsor-funded projects in fiber optics resulting from the initial IED work totaled over $500k. Some of the outstanding developments are:

1. A Six-Station Fiber Optic Telephone System was developed for USS LITTLE ROCK (CLG4) under the Navy Science Assistance Program, 62753N ZF32.319.001 (NELC S202). It communicates secure intelligence between users. Shipboard installation was made in early July 1973 and test results were excellent. Reference—NELC TD 260, Preliminary Technical Manual: Telephone System—Fiber Optic Model S202, 19 July 1973.

2. A PTTI (Precise Time and Time Interval) Fiber Optic Link was delivered to NRL for installation at a PTTI site in Hawaii. It was funded by NAVELEX 62714N XF03.532.010 and XF03.533.001 (NELC F205).

3. A shipboard closed-circuit TV using fiber optic bundles to carry video information is ready to be installed aboard KITTYHAWK (CVE 63). It was funded by NAVELEX 62755N XF54.545.022 (NELC F219).

Atmospheric Sciences



Magnetospheric Instability

Some military communication systems are severely affected by changes in the ionosphere caused by magnetospheric-ionospheric coupling. For example, vlf systems are degraded by small increases in ionization beyond ambient levels in the lower ionosphere. Hf and higher-frequency systems can be similarly affected.

A search for the mechanisms by which magnetospheric particles are caused to precipitate into the ionosphere to vary ionization levels is underway at NELC.

A "quick look" feasibility study showed that whistlers, launched from ground-based transmitters, can be used to cause particle precipitation. Aeronomical aspects indicated that a flux of about 10^4-10^5 e/cm^2/sec can cause D-region ionization. The study also indicated the need for a definitive experimental program to measure the parameters to optimize wave-particle interactions in the magnetosphere and measure the subsequent precipitation.

An experiment is planned to launch whistler-mode waves in FY74 and to detect electron precipitation by use of vlf propagation measurements along with correlation of satellite particle data.

ZR021.01
(NELC Z177)

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Bioelectronics

Diagnosis of Color Anomalies by Means of the Evoked Cortical Potential

C. T. White

The major aim of this research was to find whether recordings of the electrical activity of the visual system can be used to detect color weakness and color blindness. Additional aims included the related goals of obtaining better understanding of the functioning of the human visual system and of its responsiveness to different colors.

One problem in color response research is that the electrical activity of the visual system is apparently dominated by sensitivity to form. When any defined shape is present, the response to color is lost or submerged in the response to the form. This problem was minimized and more nearly pure color responses were obtained in FY72 by using specially constructed goggles which blur a subject's visual field.

A second problem is that there are sizable individual differences among subjects reacting to the same stimulus conditions. Third is that a subject's responses to different colors may appear to be only slightly different. In FY73 the latter problems were reduced by developing and using special recording procedures, by examining the changes in electrical activity which occurred under a variety of conditions, and by seeking intersubject similarities in the *trends of changes* in waveform shape with systematic variation of stimulus conditions. Particularly helpful in eliciting different responses is the use of varying combinations of color and brightness for both the stimulus flash and the background.

Use of these techniques has brought forth strong evidence for the presence of three sets of components of electrical activity which are differentially affected depending on the wavelengths of the stimulus and background lights. Each of the three components appears maximally to stimulation with red, green, or blue light, although all are present simultaneously, differing in amplitudes under most stimulus conditions. Together with the two components which have been identified as related to patterned stimuli, these three sets of components may account for most of the electrical activity of the visual system occurring from 100 to 250 msec after flash stimulation.

Recordings obtained from color-weak subjects were found to differ from those obtained from normal subjects. Red-blind subjects produce waveforms which are lacking the expected "red" components. Green-blind subjects produce waveforms which suggest that their visual system is attuned to different bands of wavelengths. The experiments indicate that in addition to identifying color-weak or color-blind subjects, electrophysiological responses of the visual system may also indicate something about the nature of the color defect. A better understanding of the origin and character of color blindness may result.

Knowledge gained from recordings of the electrical activity of the visual system may prove valuable in the evaluation of color vision of Navy personnel and in the design and location of warning lights and displays.

Another area of investigation has involved the use of small spots of colored illumination occurring at different points in the visual field. Marked changes in responses have been obtained depending on the angle of regard. From the standardized recording position, over the occipital lobe of the brain, the maximum response is obtained to flashes of 1-degree spots of light coming from 5 to 10 degrees into the lower visual field—that is, below the point of fixation. Whether the magnitude of the response is related in any way to phenomenal or behavioral aspects of the subject has yet to be determined. Potential application to the design of control panels, warning indicators, etc., might follow from extended research.

All the recordings made, both from full-field and spot stimulation, contribute to the knowledge of the visual system of humans. In addition, because recordings were made from both the scalp and the eye (over the cortical and receptor areas, respectively), it is possible to obtain some indication of the locations of centers of the visual system which are the source of the components identified in the waveforms. The results of this research technique may greatly increase the understanding of the functioning of the human visual system.

As the major objective of this research is to develop an objective test for color weakness, plans are to continue gathering color responses from subjects with various types of color deficiencies. When the

basic techniques have been developed, they may be applied to testing and evaluating the color vision of Navy and civilian personnel.

The basic advances made by this research will ultimately have direct application to the development of an understanding of the responsivity and functioning of the visual system of the human. This understanding will have considerable impact in clinical areas; it may result in improved diagnostic and remedial procedures. In addition, knowledge of the functioning of the visual system will contribute to a better understanding of the total functioning of the human nervous system.

PUBLICATIONS

Martin, J. I., "Effects of Angle of Regard on the Visually Evoked Cortical Potential Obtained With Small Spots of Colored Stimulation," American Journal of Optometry, American Academy of Optometry.

White, C. T., and Hanson, D., "Complex Binocular Interaction and Other Effects in the Visual Evoked Response," American Journal of Optometry, American Academy of Optometry

White, C. T., "Visual Evoked Response and Patterned Stimuli," a chapter in a forthcoming book edited by A. Riesen, University of California, Riverside, California

White, C. T., "Visual Testing With Evoked Potentials."

Three additional papers are intended to describe the work on color responses in detail:

A paper to be submitted to *Science*

A more detailed paper for *Vision Research*

A monograph to be published as an NELC report.

ZR041.01
(NELC Z167)

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Bioelectronic Study of Sea Mammals

C. T. White

Records of the visually evoked responses (VERs), electroretinograms (ERGs), and brain-wave activity of sea lions have been obtained in this series of experiments, which is expected to feed into Navy sensing system development programs. The recordings give new understanding of the visual system of the sea lion.

Preliminary results indicate that the ERG of sea lions is most responsive to stimulation with wavelengths from the blue, green, and orange portions of the human's visible spectrum. Stimulation with red light appears to produce small, but measurable, ERGs in the sea lion. When the stimulus and the background are varied in brightness, the changes which occur in the response of the sea lion closely parallel those which occur in the response of humans. Preliminary indications are that the sea lion, like the human, may possess a two-process visual system, with rod-like and cone-like functions exhibited in the ERG. Some defects of the visual system may be recognized by ERG recordings.

Hardwiring and telemetry are two methods which can be used to obtain biopotential data. Hardwired surface electrodes permit nonintrusive techniques to be used. Noise-free, reliable, and highly replicable ERGs have been obtained from the eyes of sea lions with techniques and amplifying circuits designed and developed at NELC. With electrodes over the occipital lobe of the sea lion, VERs to stimulation with flashes of light have also been successfully recorded from the brain.

Work with colors and patterns suggests that the VER recorded at the scalp of the anesthetized sea lion is differentially sensitive to variations in these factors. The sea lion's eye cannot be refracted by conventional means, because it is different from the human eye.

An attempt was made to ascertain the visual sensitivity of the sea lion by presenting different sizes of check pattern stimuli. The findings suggest that recordings of the brain waves may enable scientists to determine the visual acuity of the sea lion by this technique.

A telemetry system has been designed to permit recording from unrestrained animals. Tests on the fidelity of the total system in transmitting human brainwave patterns through a small tank filled with sea water were performed. Results were excellent and very similar to those obtained through hardwiring; however, when the system was tested in a 30-foot tank, transmission was highly directional and range was inadequate. Therefore, the telemetry unit was redesigned for ultrasonic instead of electromagnetic transmission. It will be tested when difficulties encountered in obtaining the needed ultrasonic transducers are overcome.

One of the drawbacks of using a telemetry unit for transmission from a free-swimming animal is that the electrodes, and possibly the transmitter, will have to be implanted.

Sensitivity and threshold studies with sea mammals will continue in order to obtain solid, conclusive results concerning characteristics of both visual and auditory sensory modalities. The clinical and experimental utility of biopotential recordings for working with sea mammals will be further developed. Efforts to obtain recordings from unrestrained animals will be made.

PUBLICATIONS

Martin, J. I., White, C. T., Kataoka, R. W., and Stevens, I., "Electroretinograms (ERGs) and Visually Evoked Responses (VERs) in the California Sea Lion (Zalophus Californianus)." This was submitted as an NELC Technical Document. A short paper on the general findings will be submitted to *Science* or *Psychonomic Science*, and a more detailed paper will be submitted to *Journal of Electroencephalography and Clinical Neurophysiology*.

ZR041.01
(NELC 2173)

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225-6677

Biopotential Technology

Techniques and equipments developed at NELC with relation to bioelectric phenomena are in use here and at Balboa Naval Hospital. Applications such as aircraft fire control via pilot eye movement may be feasible.

This task is a study of biopotentials and their application in both clinical and weapon systems. The goal of the first phase of this ongoing research project was to establish a baseline for the development of a biopotential technology.

A literature search was conducted covering electroencephalograms (EEGs), electromyograms (EMGs), and electrooculograms (EOGs). Personal communication with laboratories doing similar research was initiated through visits. Information was gathered on the latest methods and equipment for recording bioelectric phenomena.

The areas of specific study included methods, techniques, and electronic equipment for recording bioelectric phenomena. A technical note was written at the conclusion of each phase of the project. The notes are briefly described below:

TN 2257, Hershel, R., and Kataoka, R., "Optical Analog Biofeedback Control and Learning Devices," 25 January 1973

Promising techniques and concepts using incoherent optical computers for analyzing single-channel and multichannel data for control and biofeedback applications are discussed. This was a joint study with Electro-Optics Technology Division (Code 2500).

TN 2280, Kataoka, R. W., "A Simple Method of Attaching Electrodes to the Head for EEG Recordings," 5 February 1973

A simple and inexpensive headband and electrode system is described. This method of electrode attachment is being used by the Biosystems Research Group at NELC and by the Ophthalmology Research Laboratory at Balboa Naval Hospital.

TN 2315, Kataoka, R. W., and Allen, C. R., "A Pulse Generator for Evoked Potentials," 7 March 1973

Recording of visually evoked cortical potentials with a periodic stimulus has been shown to cause variations in responses due to habituation and fatigue effects on the subject. This technical note describes an aperiodic pulse generator which was designed and built to overcome these problems. The pulse generator is being used at the Biosystem Research Group at NELC.

TN 2335, Kataoka, R. W., "Review of EOG Recording Methods," 29 March 1973

The various methods of recording eye movement and position are discussed. The EOG method of recording eye position was studied for feasibility in monitoring a pilot's eyes to direct the fire control system of an aircraft. This monitoring method can be adapted to a clinical application of determining abnormalities in the eye's movement.

TN 2360, Kataoka, R. W., "An Amplifier for Visually Evoked Potentials," 25 April 1973

An amplifier specifically designed and built for measuring evoked cortical potentials is described. The study was jointly funded by BUMED (S101). The amplifier is being used at the Ophthalmology Research Laboratory at Balboa Naval Hospital.

TN____, "An EOG Amplifier" (in preparation)

The design and performance of an amplifier built for recording EOGs is described. This project was done jointly by Human Factors Technology Division (Code 3400), Display Systems Technology Division (Code 3100), and Decision and Control Technology Division (Code 3300) with support from NAVAIR (N447).

PUBLICATIONS

Technical notes published during the year are identified above.

ZR041.01
(NELC Z181)

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225-6677

Simultaneous Automatic Recording and Automatic Processing of Echocardiograms and Other Physiological Data

An effort to develop techniques for automated analysis of physiological data obtained from non-invasive heart disease diagnosis methods has been undertaken at NELC as part of a joint biomedical engineering program with Naval Hospital, San Diego (NHSD). The automated analysis techniques are to be used to allow screening of a large number of Navy Hospital patients without unduly increasing the burden on the physician. Large data banks could be built up from the information derived from this screening, giving heart disease history of particular patients as well as data on various types of heart disease. The data bank would provide NHSD with a unique facility for contributing to the advancement of new techniques in early detection and diagnosis of heart disease.

This program will provide automated analysis of the echocardiogram, which utilizes pulses of ultrasonic energy to visualize internal tissues. It will complement the previously developed Systolic Time Interval analysis program, and will provide a method for simultaneously recording the echocardiogram and all data for the Systolic Time Interval analysis (electrocardiogram, phonocardiogram, carotid artery tracing, and apexcardiogram).

Initial steps included familiarization with echocardiogram techniques and heart physiology through close coordination with physicians and technicians at NHSD.

Multichannel recorders capable of handling the high bandwidth requirements of the echocardiogram data (in excess of 500 kHz) were obtained by NELC. The recorders have a slow playback capability which allows matching data rates to computer capabilities.

Computer programs were developed in the area of preprocessing techniques to enhance the data for more efficient analysis. They include signal averaging, moving-target-indicator techniques, and calculation of the data signature.

At present, efforts are concentrated on the development of an analysis algorithm for the echocardiogram of the left ventricle. The completed program will provide left ventricular volumes, dimensions, ejection fractions, and circumferential fiber shortening rates. These measurements will be of high accuracy and can be averaged over many heartbeats. The figure shows the results of the application of the algorithm to pick out the left ventricular heart wall and septum. The exaggerated peaks are placed in the data by the computer to show where the wall and septum were determined to be. Their locations are stored and can be recalled to calculate required parameters. Development of the left ventricular analysis algorithm will pave the way for more complex areas of analysis.

ZR041.20
(NELC Z182)

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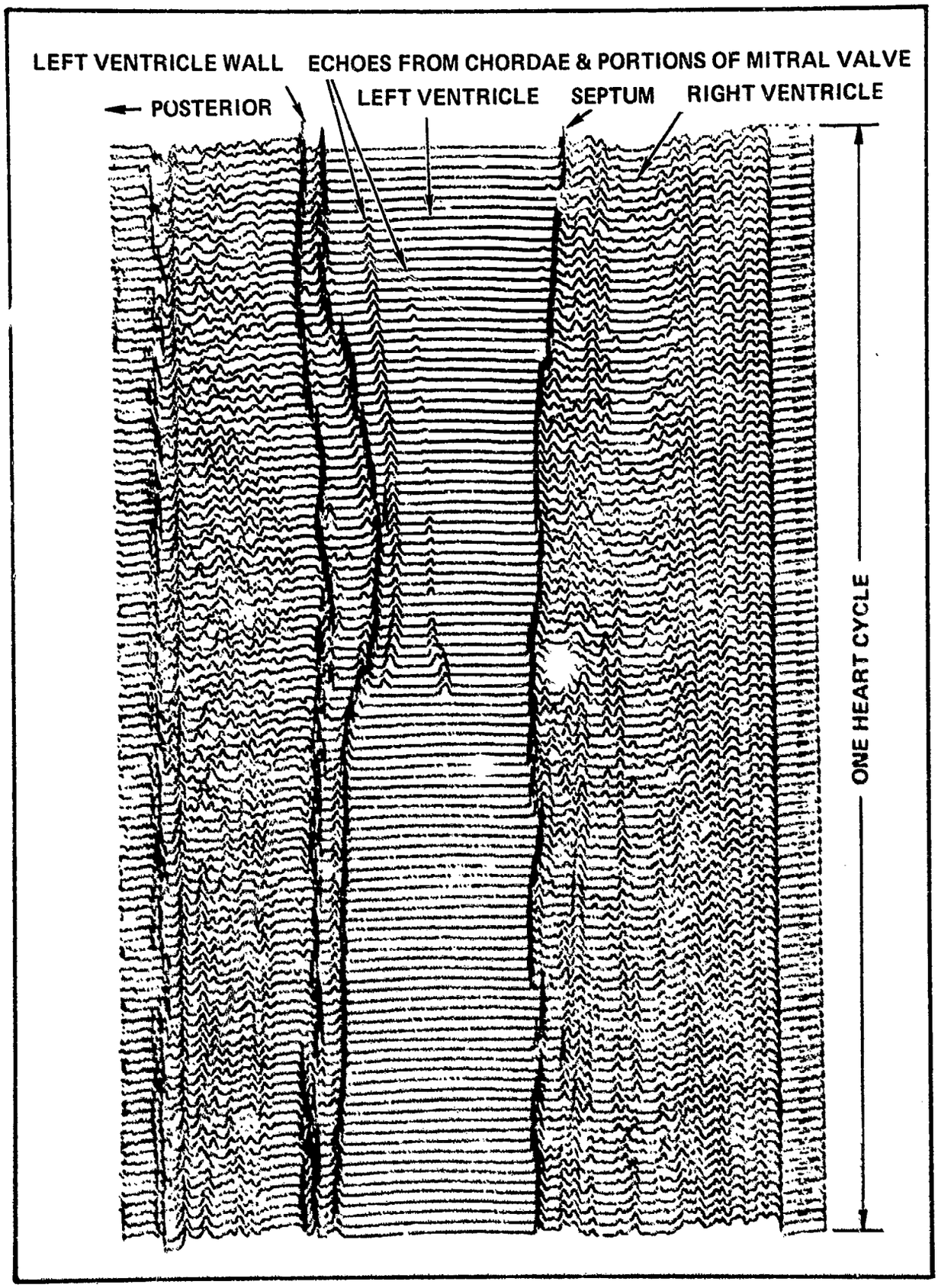
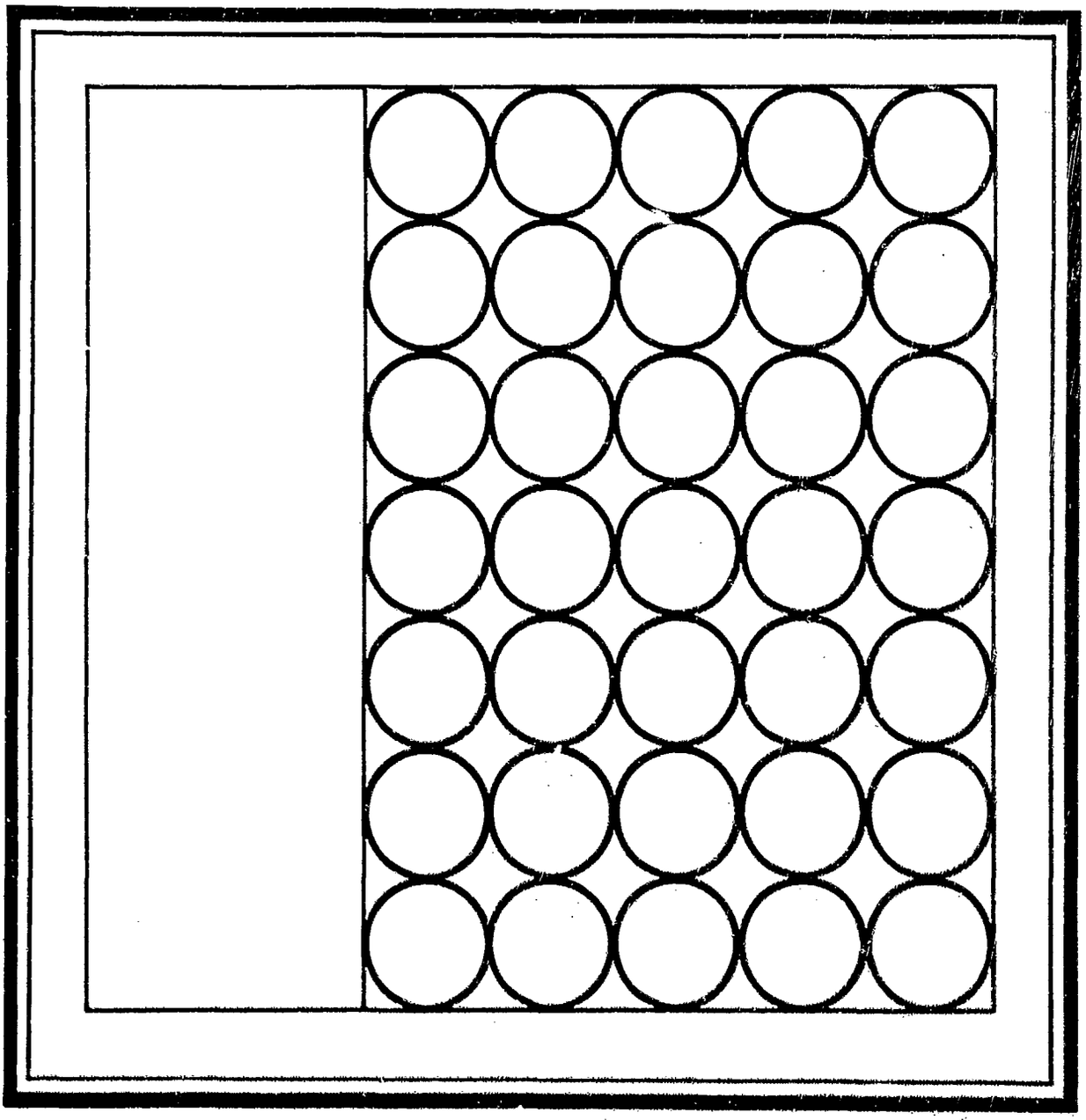
225-6257/7778



Computer-reproduced echocardiogram of left ventricle. The left ventricular wall and septum have been located by the computer algorithm and their location indicated by exaggerated peaks in the data.

Display Technology



Specialized New Phosphor Materials for Application to Optical Display and Sensor Technology

The wave of innovative applications of luminescent materials in recent years makes necessary a continuing effort on the part of NELC to keep abreast of new developments and to expedite their early introduction into new and existing systems. These materials have made possible wide-ranging improvements in the areas of command control display technology, infrared-to-visible image conversion, sensor development, and solid-state lasers. Of special interest are the unique luminescent properties of rare-earth materials. Their multicolor, high-brightness, and narrow-band emissions find useful application in projection CRT screens and high-voltage postmagnetic deflection tubes. The practicality of using matched narrow spectral filters to effect contrast enhancement in CRT screens—the result of their durability, long life, and extreme resistance to thermal burn and electronic aging under bombardment by high-voltage electron beam currents—justifies a detailed examination of selected materials having unusual luminescent properties and excitation mechanisms.

Luminescent materials—among them the rare earths—can enhance capabilities in command control display, IR-to-visible image conversion, and sensor systems. Some specific applications: solid-state lasers, projection CRT screens, deflection tubes, and flat-panel displays.

During FY73, NELC examined the photoluminescent and cathodoluminescent emissions of $LiYF_4$:Pr, $Gd_2(MoO_4)_3$:Eu, YVO_4:Eu, and LaF_3:Tb in the visible and infrared spectral regions. Their cathodoluminescent properties were studied in a demountable CRT system developed to provide absolute spectral radiance measurements of phosphor screens. Spectra were taken at various current densities and voltages up to 19 kV.

The photoluminescence and cathodoluminescence of several cerium-doped compounds—CeF_3, LaF_3:Ce, $CaMoO_4$:$CeNbO_4$—were investigated for their intense UV emission and considered for use as improved and durable cascade phosphors to replace or improve present P16 screens.

A multievaporating system has been designed and built for the evaporation of multilayered structures. The system will be used for examining thin light-emitting films for use in flat-panel electroluminescent display consoles. The effort in FY74 will be directed toward materials capable of emitting various colors at low voltages.

PUBLICATIONS

Optical Properties of New Phosphor Materials—$LiYF_4:Pr^{3+}$," NELC Technical Note (in preparation)

Spectral Emission Properties of Phosphors Under Cathode-Ray Excitation," NELC Interim Report 2640-1, January 1973

Martin, H. R., "Facsimile Recorder Paper Survey," NELC Memorandum Report, September 1973

ZR011.02
(NELC Z163)

Contact
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225-6591

Liquid Crystal Devices

The Liquid Crystal Devices Program was begun in late December 1971 to investigate the electro-optical properties of liquid crystals (LCs) and explore potential Navy applications of LC devices. During the initial phase of the FY73 project several potential applications were investigated for feasibility, and the following three devices were selected for full emphasis: an automatic selective spatial attenuator, a refreshable multichannel memory for an optical correlator, and an active coupler/switch for optical communication waveguides.

Since commercial LC materials were tested and found to be low in purity – as indicated by inconsistent behavior, short lifetime, and, to some extent, resistance to molecular alignment at the film interfaces – the decision was made to concentrate emphasis on a single device application, the correlator memory, and to procure, if possible, an LC photoactivated cell suitable for establishing feasibility. All known companies with LC device fabrication capability were contacted as possible suppliers. The only company which was both willing to respond and able to deliver at reasonable cost supplied a photoactivated LC storage memory cell. The cell was evaluated in the Incoherent Optical Sonar Correlator system under development at NELC (project N608) and was found to be easily equivalent in performance to the high-contrast photographic film presently used in the system. We are now considering optimum means of updating the memory information stored in such a device in a manner consistent with the simplicity, speed, and small size of the NELC correlator.

ZF61.212
(NELC Z252)

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225-6641

Liquid Crystal Display Techniques

Previous research had demonstrated that liquid crystal cells have great potential for application in projection large-screen displays and displays in general and also show promise as variable-persistence displays, real-time operating light valves, color filters, and variable light attenuators. In FY73 NELC investigated the use of liquid crystal cells as a light valve device primarily to generate hard copy from CRT displays.

Currently available CRT hard-copy devices require very high intensity CRTs and an expensive lens system if an image is to be projected onto photosensitive paper to make a hard copy. Other techniques have been used which entail sampling and line-at-a-time techniques. These methods do not produce the high-quality image required for photo work. Furthermore, they require precision mechanical paper transports and a dedicated refresh for the entire exposure time.

It will be possible to obtain high-quality hard copy at low cost if a liquid crystal device can be developed that is sensitive enough for a low-intensity CRT to activate and which can be used as a light valve to project the CRT image.

An inexpensive experimental device uses a sensitive photoactivated liquid crystal cell and a small collimated light source to provide both positive and negative images. This technique may soon make it possible to obtain high-quality hard copy from CRT displays at low cost.

Tests were made on three different photoactivated liquid crystal cells to determine sensitivity, storage characteristics, and contrast ratio of the stored image. The tests were made on cells which are basically nematic with a small amount of cholesteric material added to provide storage.

Stored images were projected with a small collimated light source. A f/2.8 50-mm projection lens was used to focus the scattered light rays from the liquid crystal cells via a 45° front surface mirror with a small aperture in the center. The collimated light that was not scattered by the stored image in the liquid was focused to a point by the projection lens, passed through a 3/8"-diameter hole in the mirror, and focused on a screen. This image is a negative of the stored liquid crystal image. The positive image is reflected from the mirror surface. Thus, both positive and negative images can be obtained from this device.

The dc storage cells tested had resolution of better than 26 line pairs/mm. The storage units had poor sensitivity and no gray scale capability, while the nonstorage unit had good sensitivity (enough for activation with a standard 9" TV monitor and an inexpensive lens) and good gray scale as well.

Further basic and applied research is needed to improve sensitivity and gray scale capability and to increase life of the dc photoactivated cell. Investigations and tests on new ac long-life cells are planned.

ZR021.03
(NELC Z183)

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225-6762

Command Control Display Module

NELC began to modularize display systems in 1971. FY73 saw progress in packaging, performance, and application. NELC built a successful 10-MHz stroke generator with its first modules—followed it with a digital processor, an interface for multiplexable displays, a serial encoder, and line drivers.

BACKGROUND

This investigation began in 1971 with the partitioning of known NTDS display systems into display modules that seemed appropriate for good system architecture. Modules were designed from this base with transistor-transistor logic. A group of modules was used to demonstrate a 10-MHz stroke generator. These early modules provided encouraging performance. A second effort was mounted in FY72 to eliminate the shortcomings of the test modules and extend their performance and packaging to a more sophisticated problem. The problem involved the development of a digital processor capable of driving and exercising a display system under Z247 (Improved Techniques for Advanced Shipboard Display Systems). In addition to the processor, a set of cards was developed that could be utilized for the direct interface with a large number of multiplexable displays. This set of three cards has the capability of interfacing with electroluminescent, light-emitting-diode, plasma, and other types of displays suitable for multiplexing. After the successful operation of the processor and display drivers, programming was developed for the processor to permit the proper operation and manipulation of the Z247 displays for all required conditions.

ACCOMPLISHMENT IN FY73

The software programs initiated in FY72 were completed and extended to operate new displays that were included in the Z247 program. The final card configurations considered as successful are:

Arithmetic Logic Unit (ALU)
Free Logic Unit (FLU)
Binary Asynchronous Reconfigurable Formatter (BARF)
Serial/Parallel Loader And Transceiver (SPLAT)
Decision Tree
Control Memory Control (CMC)
Bootstrap
Function Control
Advanced Alphanumeric Digit Driver Group (AADDG)

The module investigation was extended to higher frequencies and analog circuits, involving the development of new techniques. These techniques are required for the operation of very-high-speed data communication links that would be suitable for solving a class of problems represented by a centrally located system symbol generator. The selected approach used Miller serial encoders constructed with emitter-coupled logic and operated at 80 MHz. These circuits were constructed and tested under simulated operating conditions. To enhance the operation of the Miller encoders, line drivers capable of driving 1000 feet of coaxial cable were packaged as hybrid circuits that could be coupled to the serial modules. This completed the source end of the serial symbol generator. To complete the development, a high-speed D/A converter capable of accepting 10-MHz stroke-type digital information and creating the required analog voltages to operate a CRT deflection amplifier was designed. The analog information was created at the required speed and quality, but the system was not completed when it became apparent that the packaging scheme for the module was not suitable for operation at frequencies of 80 MHz.

High-speed nonvolatile memories of the amorphous type were tested as a part of the search to find a suitable memory for a system of this type.

The results of this program are being utilized on project 2175 (2 to 1 improvement in life-cycle costs of Navy Electronics by 1975), N416 (Display Technology for Command Control Data Systems), and N433 (Display System Analysis and Support).

ZF61.212
(NELC Z238)

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225-6541

At-Sea Tactical Command Control Systems Study

The At-Sea Tactical Command Control Systems (ASTC^{2}S) Study was conducted during the period July 1972–January 1973 by an NELC group comprised of representatives from the various NELC departments. Its scope was limited to at-sea tactical command control systems because of the vast amount of material to be covered in a short time.

The fir. . report of the study group provided an assessment of the operational effectiveness of the Navy's current and future at-sea tactical command control systems, identified system deficiencies, and recommended means for correcting or alleviating certain of these deficiencies. This report gives a base from which system planners can develop, design, and implement improved Navy command control systems.

ZF61.212
(NELC Z259)

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225-2208

Improved Techniques for Advanced Shipboard Display Systems

Current flat-panel display technologies are characterized with respect to optical and electrical parameters critical in military applications. Variable-persistence phosphor screens are evaluated as candidates for use in dual-persistence CRT displays of radar and sonar data.

FY72

A display demonstrator containing samples of four flat-panel display technologies—gas discharge or plasma, light-emitting diode (LED), liquid crystal (LC), and electroluminescent (EL)—was constructed and interfaced to a special digital processor developed under Z238 (Command Control Display Module). The system permits manual entry, format modification, and special test modes for evaluating and demonstrating the performance and behavior of the displays. Displays which are contained in the display demonstrator include:

Plasma displays containing 512 x 512 positions over an area 8½ x 8½ inches, and eight rows of alphanumerics 32 characters per row in 5x7 format

Seven-segment LEDs in red, yellow, and green for numeric readout, and 5x7 arrays for alphanumeric displays

Scattering and field-effect liquid crystals for seven-segment and 16-segment indicators

An electroluminescent alphanumeric 16-segment display

FY73

This year's activities have been centered on the characterization of the various displays contained in the display demonstrator. The display evaluations have been directed toward determining the optical and electrical parameters judged critical in military applications. In addition to the optical measurements necessary for the selection of displays, the factors affecting the speeds of data refresh and update have been examined. These data reduce to parameters of cost, application, and environmental factors which either enhance or detract from the potential usefulness of the display to the Navy.

The need for dual-persistence CRT displays in radar and sonar prompted continued investigation into variable-persistence phosphor screens. Such display screens could provide the required performance for a variety of display applications. Approaches taken included single, mixed, and layered phosphor structures. Specific approaches included:

ZnCdS:Ag,Ni; ZnS:Cu,Ni; and ZnS:Cu phosphors, which are excited by UV radiation and quenched by IR radiation. Substitution of electron excitation did not result in required performance.

The same phosphors were examined in cascade configuration with electron-excited UV-emitting phosphors P16 and P11 used for energizing.

The most promising phosphors are ZnCdS:Cu,Mn,Ni and ZnS:Pb,Mn, which are UV energized and IR excited. These phosphors are used in cascade configuration.

PUBLICATIONS

"Flat Panel Displays—Who Needs One?" a paper presented by F. C. Martin, Jr., to both the Society for Information Display (SID) and the American Ordnance Association (AOA), was published in the vol 10, no 2, March/April 1973 issue of the *SID Journal*.

ZF61.212
(NELC Z247)

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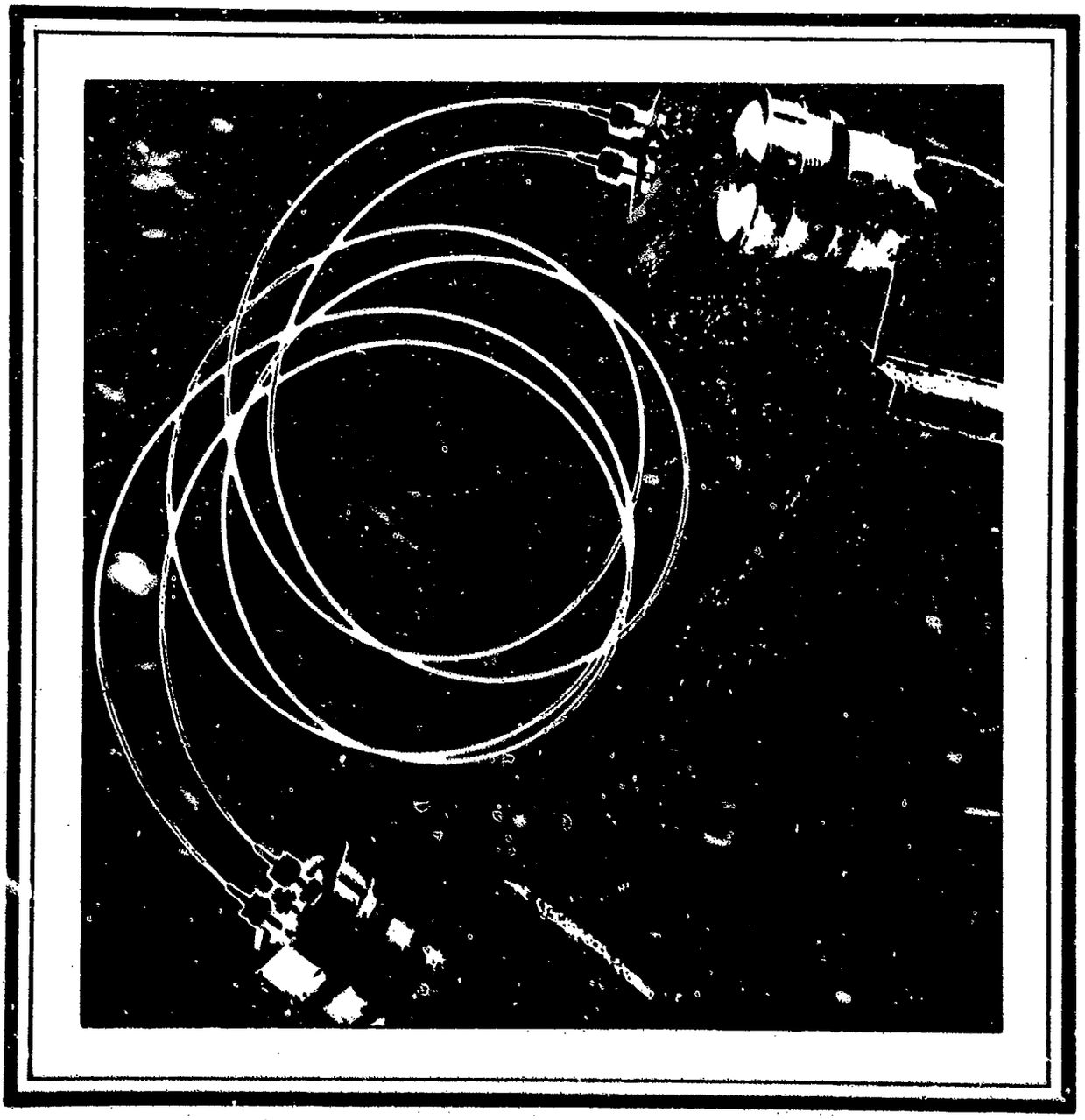
225-6541

Electrooptics



Guided Wave Optics

The provocative advantages of optical communication—security, reliability, and economy, among others—will be accessible to the Navy only when system components are at hand. NELC is fabricating waveguides and studying coupling, modulation, and guided wave behavior under this problem.

Optical waveguides and electrooptic waveguide modulators for potential use in optical communications have been fabricated by diffusing cadmium into ZnSe and selenium in CdS single-crystal substrates. Also, waveguiding and electrooptic modulation have been observed in ZnSe and ZnS heteroepitaxial films on GaAs substrates.

The work in fabricating the guides and testing their material properties has been performed under the Integrated Optics Technology Program for FY73. The Z162 program for this time period has been a supportive one that encompassed theoretical work and diagnostic techniques on understanding guided wave behavior in the various waveguide structures.

Three separate areas were explored in the Z162 program. The first involved the analysis of leaky waveguide modes in the heteroepitaxial ZnSe films on GaAs. The index of the film is lower than that of the substrate; thus, optical guiding in the usual sense with total internal reflection at the film-substrate interface does not occur. These structures were studied both experimentally and theoretically. It was concluded that the leaky modes were propagated with very low losses (<3 dB/cm) in films over 5 μm thick and that these films are therefore practical candidates for electrooptic modulation.

The second area was a study of the prism as a device for coupling light from an external laser beam into the diffused and heteroepitaxial films and as a diagnostic device to study guided mode behavior in these films. High-index rutile prisms and jigs were constructed to perform the optical coupling experiments. These experiments were not successful and focused beam coupling into the end of the guide is still the easiest and best way to provide the coupling. Various other schemes to yield coupling into the guides with higher efficiency will be investigated.

The last area explored was the cw intensity modulation of light in some of the diffused waveguide structures. Preliminary work is to be continued on measuring the performance characteristics of the modulators. The best result to date was 30% amplitude modulation at 140 MHz.

PUBLICATIONS

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Hall, D. B., NELC Technical Report 1861, "Integrated Optical Circuits," 30 January 1973

ZR011.12
(NELC Z162)

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Optical Waveguide Propagation Theory

Theoretical analysis of propagation in optical waveguides can afford valuable design criteria, particularly regarding performance and size of components. Specific requirements generally involve calculation of waveguide modal constants and can involve dispersion, mode conversion, radiation losses, and mode excitation, as well as other phenomena.

During the past year efforts have been directed towards

1. Developing computational techniques for inhomogeneous anisotropic planar waveguides along the lines of Budden's formalism [ref 1], which has been successfully applied in radio propagation studies relating to the earth-ionosphere waveguide [ref 2 and 3].

2. Extending to these more complicated systems the analysis of prism and periodic couplers developed by a number of investigators for isotropic planar waveguides.

Advantages and disadvantages of numerical techniques described in (1) above have been examined for the three-layer optical waveguide and for the general inhomogeneous or multilayered plane waveguide. It has been concluded that Runge-Kutta integration of the reflection coefficients is not in general as powerful a technique for optical waveguide studies as it is for radio propagation studies. The reason for this is that the abrupt changes in index of refraction which so often occur in optical waveguides severely slow the numerical integration. A more powerful approach appears to be associated with field matching at the boundaries of a multislab guide, and it is this technique which serves as the basis for the program developed to handle the inhomogeneous guide (see PUBLICATIONS below). To extend this technique to the anisotropic planar guide as well as to the problem of calculating height gain functions of the normal modes requires further refinements. These refinements now appear feasible and worthwhile, since modulation and two-pole switching of laser light at frequencies up to 80 MHz have recently been reported in magnetooptic garnet films [ref 4]. More generally, such capability would be useful for analyzing a variety of nonreciprocal devices.

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Pappert, R. A., "Plane Wave Theory of Prism and Periodic Couplers for Inhomogeneous Anisotropic Slab Waveguides," NELC Technical Note (in preparation)

ZR011.12
(NELC Z187)

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225-7688

Tunable Spin-Flip Raman Laser

Current communication systems using microwave frequencies do not have sufficient spatial resolution to prevent interception of a "secure" transmission. The objective of this program is to provide a method for restricting communication to the intended receiver only. A spin-flip Raman laser (SFRL) is under development to provide continuously tunable, coherent radiation in the spectral ranges of 5 to 6 μm and 9 to 14 μm for use as a major component in a tunable laser transmitter. A newly discovered process which makes tuning feasible is being applied for the first time to optical communications at NELC, and could be incorporated in future versions of OCCULT. The main components of the SFRL and progress toward development of them are outlined below.

The tunable SFRL under development at NELC will be a major component of a tunable laser transmitter for use in covert communications.

A fixed-frequency pump laser is used to generate stimulated Raman scattering in a semiconductor which is shaped as an optical resonator. The frequency of the Raman-scattered radiation depends on an applied magnetic field according to the relation

$$\omega_S = \omega_L - g\beta H$$

where ω_S is the scattered frequency, ω_L is the pump frequency, g is the effective electron g-factor, β is the Bohr magneton, and H is the magnetic field.

Tunable spin-flip Raman laser emission has been achieved in the 5.3-μm range in experiments using InSb as the stimulated Raman material. The pump laser was constructed at NELC and operates single frequency continuous wave with either CO_2 or CO as the active gas. Provision will be made for Q-switching the CO_2 laser for operation in the 9–11-μm range, but at present we shall continue to operate continuous wave with CO-laser pumping.

The single crystal of InSb is cut and polished to form a Fabry-Perot resonator. The electron concentration is about 10^{15} cm^{-3} at 77K. This type of material was shown to require the lowest magnetic field for SFRL operation when pumped at 5.3 μm. The sample is held in a cold finger which mounts in the coil of a superconducting magnet and maintains the temperature of the sample below 20K. The superconducting magnet has operated at fields up to 20 kG. This field strength is adequate for pumping InSb at 5.3 μm but not at 10.6 μm. Although high magnetic fields are not necessary for InSb SFRL pumped at 5.3 μm, it is convenient to use a superconducting magnet because of the low sample temperatures. A new magnet is now available to permit operation up to 60 kG, increasing tuning range and reducing temperature requirements.

The next phase of development of the SFRL will involve improvements in the cooling of the Raman resonator and design of a magnetic field frequency modulator.

Another objective of this program is to analyze atmospheric absorption spectra for structure which can be used in covert communications. These same spectral features are of direct importance in the propagation of high-energy infrared laser beams through the atmosphere. Since the SFRL is a continuously tunable source of radiation with a line width of a few kilohertz or less, it can be used with a suitable absorption cell to measure atmospheric absorption with extremely high sensitivity and resolution unachievable by other means. These measurements are planned as part of the FY74 program.

ZR011.07
(NELC Z164)

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Electrooptic Crystal Storage

Information storage capacity and access speed can be limiting factors in the performance of command control systems. Recent technological advances have made three-dimensional holographic storage in electrooptic crystals an attractive candidate for high-capacity, fast, low-cost memories of the future. Capacity of 10^{12} bits, random-access time of 10^{-5} second, and cost of 10^{-5} cent/bit seem feasible. High-density archival storage of documents containing such information as maps, charts, environmental details, sensor reference data, and medical records is another attractive possibility.

During FY73, the first year of this program, phase gratings with resolutions as high as 2000 lines/mm were stored holographically with an argon laser in iron-doped $LiNbO_3$ samples. Diffraction efficiencies for these Bragg-sensitive holograms were approximately 20% for exposure times of 30 seconds. Holograms of alphanumeric characters were stored in these crystals, and the images were examined visually and photographed. Angular sensitivity of the holograms was calculated and plans were made for experimental verification. Samples were thermally erased by heating to 250°C and used to store a new set of holograms. No degradation in performance was evident.

ZR011.02
(NELC Z180)

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225-6641

Photo-Modulating Shipboard Topside Interference Sources

Frequently naval shipboard communications are plagued by undesired signals generated in natural nonlinear junctions located in topside areas of ship superstructures. The junctions often occur in items of topside equipment such as lifelines, ladders, and boat davits. Currents induced in these structures at the fundamental frequencies of the ship transmitters supply the energy for a wide spectrum of intermodulation interference in receiving channels.

All present techniques for locating the junctions ultimately require the presence of the investigator at the junction location. On the other hand, many potential junctions exist in areas not accessible either at sea or dockside with transmitters operating. Clearly, a stand-off capability of investigating possible junctions is needed.

In this project it was postulated that the natural junctions may be photo-sensitive, as are other junctions. It might then be feasible to modulate the rf interference generated in the junction with a series of optical pulses from a low-power laser. Visible light would be desirable to mark the junction location, and low power would be needed for portable operation.

A stand-off capability of checking ship topside junctions suspected of being sources of rfi would be valuable. Photo-modulation is investigated as a possible means of providing it—and rejected.

It was necessary to arrange instrumentation which would (a) allow the observation of nonlinear junction output at some rf interference frequency, and (b) apply optical input to the junction while the foregoing observation was taking place. For simplicity, it was decided the third harmonic of the energy source fundamental frequency would be observed. This method has been successfully applied in many previous experiments and has the advantage of minimizing both the amount of equipment and the difficulty of filtering out undesired spectrum components inherently generated in the available rf sources.

Optical input to the junction was made easy by leaving the sides of the junction housing open. Light sources used included an ordinary number 5 flashlamp, a xenon flashlamp, and a laser. Initially, experiments were made with the lamps; later experiments used the laser.

It was demonstrated that the junction was photosensitive. The data indicate maximum sensitivity at the longer wavelengths, probably in the infrared.

The junction was not sufficiently sensitive at 0.633-μm wavelength to be affected by power densities on the order of 0.1 watt per square centimeter. A reasonable estimate of the power density obtained with the number 5 lamp at longer wavelengths was up to 1 watt per square centimeter.

The low sensitivity of the junction makes the location of interference-generating junctions in the shipboard topside environment by optical techniques unattractive. It appears that a carbon dioxide laser having on the order of 10 or 20 watts of output would be needed to modulate junctions at distances of 200 feet. The equipment would be heavy and bulky. Its use would entail some degree of hazard to personnel in the vicinity. For these practical reasons it is recommended the effort not be pursued further.

ZR011.07
(NELC Z185)

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225-7701

Pulsed Underwater Optical Sources

A pulsed transmitter operating in the blue-green "window" is needed for Navy underwater optical systems. NELC may have found a suitable incoherent source in zinc and cadmium vapor arc discharge lamps.

Many Navy optical underwater systems for communications, gated viewing, surveillance, and bottom mapping require pulsed transmitters in the blue-green (4600 Å to 5100 Å) spectral region. Pulsed lasers of the form of frequency-doubled neodymium at 5300 Å are commonly used for underwater systems. However, the attenuation coefficient at this wavelength is about twice as large as the minimum value for deep ocean waters. Pulsed dye lasers are being developed at NELC for this type of application [ref 1]. Their importance is their tunability to the wavelength at which the ocean attenuation has its minimum value. However, this source has its limitations because of the limited lifetime of the flashlamps and the dissociative quality of the dye. Since, for most underwater systems, the coherence properties of lasers are of little value because of the large amount of scattering, the development of a simpler transmitter – an incoherent, short-arc lamp – represents an alternative approach. The objective of this program is the spectral examination of new materials for fills of this type of lamp.

Recent experiments at NELC [ref 2] have shown that zinc and cadmium vapor arc discharge lamps as incoherent sources in the cw mode have very strong emissions in the required spectral region. The transitions are the $5\ ^3p - 6\ ^3S$ in cadmium and the $4\ ^3p - 5\ ^3S$ in zinc. As much as 80 watts has been emitted from the triplet transitions at 4680 Å, 4722 Å, and 4810 Å from a short-arc zinc lamp at an electrical input power of 2000 watts (4% efficiency).

This new program studied the time histories of incoherent emission in the pulsed mode of zinc and cadmium discharges. A better understanding of the complex radiation processes and their temporal evolution could lead to the design of a high-peak-power, efficient, inexpensive, lightweight, reliable, rugged, small-volume optical transmitter.

Time-resolved spectra of pulsed discharges of cadmium and zinc vapor arcs were recorded. A Jarrel-Ash monochromator was modified to accommodate a TRW image converter camera operated in the streak mode. Lamps of the short-arc configuration were excited by a 2.5-ohm pulse-forming network. Pulse duration was 750 nsec at a peak current of 3000 amperes. Spectral enhancement was observed with a peak power of approximately 1 kilowatt in the blue-green portion of the spectrum. The continuum radiation emission follows the current pulse, while the line emission showed a 5-μsec decay time.

This work is being continued under NELC project B403 funded by Advanced Research Projects Agency.

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ZR011.07
(NELC Z190)

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225-7975

Incoherent Optical Correlator for Active Sonar

The purpose of this project has been to develop a real-time incoherent optical correlator for use in sonar detection. The work has been a joint effort of NELC and Naval Undersea Center (NUC).

Active sonar systems require a multichannel capability to allow handling signals from a hydrophone array. This enables beam-forming techniques to be used so that directional information can be obtained on the sonar returns. Furthermore, it is desirable to have information on the range rate of targets. This is accomplished by having a separate channel for each doppler resolution element desired. Thus, there are a large number of channels to be processed simultaneously. The parallel processing capabilities of optical processors (as opposed to serial processing restrictions on electronic processors) are ideally suited to this problem. An incoherent optical correlator was designed, built, and tested which is capable of simultaneously correlating each of six different inputs with 150 different doppler-shifted references in real time.

A central element of the correlator is a mask which stores, in the form of a transparency, the reference functions for cross correlation. High-resolution photographic masks for various reference functions were obtained through a contract with the University of Arizona Optical Sciences Center. Real-time updatable masks were also investigated. In particular, a liquid crystal device was tested in the optical correlator and found to perform as well as photographic film.

This system was tested on signals of the type that would be used in active sonar. A linear FM signal with 100-Hz bandwidth and time duration of 1 second (that is, with a time-bandwidth product of 100) was shown to give good correlation. Noise-immunity measurements were taken for this signal, and the system was found to have a measured processing gain of 10 dB in agreement with theoretical predictions.

A NELC technical report was written covering this work. It describes the system and its design parameters in detail. The results obtained and recommendations for further work are given.

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ZF61.112
(NELC Z250)

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225-6641

Fiber Optics Emitter/ Detector Evaluation

In a program set up to evaluate improvements in fibers and to assess the performance of fiber optic sources and detectors, NELC has developed instrumentation and procedures and verified their adequacy by measuring the performance characteristics of photodiodes, avalanche photodiodes, LEDs, and fiber optic bundles; and fabricated a prototype glass-core coupler and a number of connectors.

The main thrust of fiber optics information transmission system development has been in the technology of the fibers themselves. Systems have generally been designed around existing light emitters and detectors and associated electronics which impose limitations on system performance. Practical sources are limited to information bandwidths of 100 MHz or even much less and require elaborate electronic multiplexing which in turn is sensitive to interference. Available detectors have limited sensitivity under wideband conditions.

In order to evaluate improvements in fibers and in general to assess the performance of fiber optics sources and detectors, it has been necessary to develop procedures and instrumentation for measuring the characteristics of these devices. The types of measurements required include optical spectral bandwidth, electrical information bandwidth and electro-optical transfer characteristics for both sources and detectors, and optical and information bandwidth of fibers. Furthermore, it has been necessary to develop efficient electronic interfacing and optical coupling of the sources and detectors to the fibers. This work is basic to NELC's contribution to the Navy fiber optics program.

In FY73 a versatile apparatus was designed and constructed for performing spectral measurements on light-emitting devices and photodetectors. This apparatus, which includes a high-resolution monochromator, provides for precise point-by-point comparisons between standard sources or detectors and devices under test. It can be used for measuring a wide variety of device types, including fiber bundles, with a minimum of setup time.

In order to measure small-signal frequency response of high-speed detectors, it was necessary to develop novel equipment providing optical signals modulated at frequencies of hundreds of megahertz. The apparatus built for this purpose uses two single-frequency neon lasers, operating at 0.63 μm, which can be tuned independently over a range of about 800 MHz. The beams from these lasers are combined to produce beats in the detector under test. The range of frequency measurements is presently limited to 500 MHz by available display equipment.

With the apparatus described above, preliminary measurements of performance characteristics of photodiodes, avalanche photodiodes, LEDs, and fiber optic bundles were made, verifying the accuracy of the measuring techniques developed under this program.

To achieve efficient coupling into and out of a fiber optic data bus, several designs were considered for data couplers. A prototype glass-core coupler was fabricated. A number of connectors for joining fiber optic bundles were also fabricated and have been submitted to Design Engineering Division (Code 4400) for testing. Splicing losses less than 2.5 dB were achieved.

ZF61.212
(NELC Z261)

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225-6591

Fiber Optic Engineering

Environmental and physical property tests were conducted under Z267 upon 200 fiber optic cables of current manufacturing types. These tests defined the suitability of such products for Navy use by evaluating their ability to withstand mechanical, environmental, and chemical test exposures of military specification levels. The initial effort evaluating cables of high optical loss was extended to include similar test assessments of the more recent low-loss cable types.

Testing of fiber optic cable, hardware, and jacketing material.

Supporting efforts on fiber optic cable hardware development were conducted which resulted in the design and test of separable optical cable connectors of modified electrical and pneumatic styles, respectively. Work was also supported to evaluate the water penetration resistance of typical fiber optic cable plastic jacketing materials. Work performed under F219 resulted in an improved circuit design for a 50-MHz light-emitting-diode digital line driver for use as a fiber optic cable light source.

PUBLICATIONS

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ZF61.212.
(NELC Z267)

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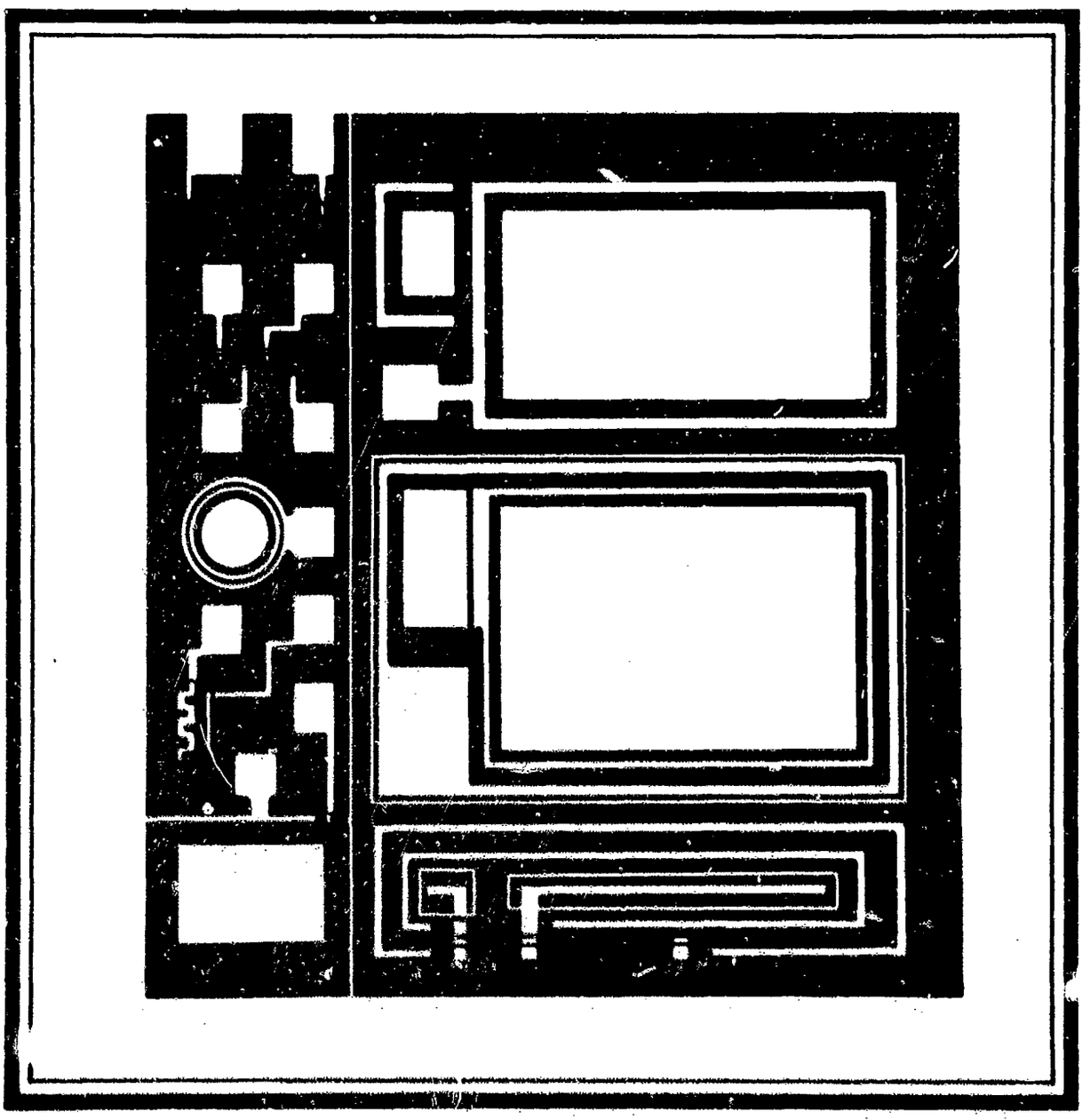
225-7296

Material Sciences and Devices



Compatible MOS/LSI and Acoustic Surface-Wave Technologies

Current investigation is aimed at developing a 15-bit quadriphase programmable correlator to demonstrate the feasibility of combining the piezoelectric film transducer technology and semiconductor MOSFET technology to achieve a truly monolithic surface-wave matched filter.

Theoretical prediction, design tradeoff, and logic design of the programmable quadriphase correlator were completed in FY72. During that year, two approaches were investigated--the hybrid, more conventional approach, which consists of a standard piezoelectric tapped delay line with rf bonding leads connected to a switching and logic chip; and the silicon approach, which ensures reliability, producibility, and elimination of isolation and crosstalk problems.

The advantages of the silicon approach make it attractive to designers of naval radar and communication systems of the near future.

During FY73, a cooperative effort between NELC and industry was instituted to implement several unique features for the silicon approach which set it apart from past investigations. A sputtered zinc oxide film transducer technique for bidirectional excitation of surface waves on the silicon was used. With these thin-film transducers in conjunction with a metalized interdigital electrode pattern, k^2 coupling constants within 90 percent of theoretical calculation for single-crystal ZnO layers were measured. With a three-pole matching network, connected at the input, operation near 60 MHz with a 20-MHz bandwidth requirement was achieved with 40-dB insertion loss, including 10 dB for the matching network. The surface-wave sensing elements (taps) were P-channel MOS structures on (110) oriented silicon wafers. The MOSFET tap structure was organized by quadrants to achieve a correlator which could generate a quadriphase signal. Figure 1 shows the CAD printout of the device with the interdigital transducer structure in the center and three MOSFET tap structures in each of four quadrants. The quadrants are offset with respect to the phase center of the transducer, representing 0°, 90°, 180°, and 270° phases. Each MOSFET tap structure had three metal-gate p-channel MOSFET sensors with drains connected to a summing line. Thus, there were 180 MOSFETs (15 bits per quadrant), each with a channel length of 5 μm and width of 1.25 mm over a chip area of approximately 0.34 x 2.45 cm^2 (135 x 580 $mils^2$). Separate gate leads were maintained so that each tap could be turned on or off independently of the other taps and provide a means of coding the device. Figure 2 illustrates the programmable correlator on its ceramic substrate with all gates independently wired.

Surface wave devices currently utilized in Navy electronic circuitry as encoders, decoders, filters, delays, etc., are discrete components. The goal of this program is to establish the feasibility of fabricating a surface wave device by typical microelectronic semiconductor processing so that the capability can be incorporated into integrated circuitry. This feasibility was established.

The performance of the programmable correlator was experimentally characterized and compared to theoretical prediction. The time response of the 15-bit MOSFET structure of one quadrant to an impulse of 10-nsec bursts of 60-MHz rf carrier every 10 μsec when applied at the transducer is shown in figure 3. The output is very uniform in amplitude at 60 MHz with no amplitude roll-off due to propagation attenuation or output tap loss. However, when only tap 15 was turned on, the output showed a triangular pulse 1.64 μsec after the leading edge of the exciting pulse. Additional pulses observed at 3.35-μsec intervals are believed to be caused by reflection of the mechanical wave at the edge of the chip. Furthermore, turning a given gate "on" results in an approximate 6-dB increase in the signal output from that transistor. Future investigation should attempt to improve this ratio.

The experimental characterization of the quadriphase programmable correlator served to identify critical design and processing techniques and to assess the strengths and weaknesses of the technology. To achieve for a given frequency and bandwidth optimum piezoresistive conversion efficiency, the use of n-channel silicon-gate MOSFETs will provide specific advantages to obtain minimum capacitance, small conductance, and higher gauge factor. The latter will improve the SNR at the output when a gate is "on" or "off." The use of smaller channel width-to-length ratio and fewer taps will help maximize the bias current density and maintain low capacitance.

The basic ZnO/MOSFET technology used in the

development of the quadriphase programmable correlator is considered a sound approach to programmable matched filters of small number of bits (30 to 40). The benefits to be derived from the integration of surface wave and silicon technologies are increased reliability, simplicity of manufacture, and lower cost.

ZR021.02
(NELC Z165)

PUBLICATIONS

Schiff, M., and Lagnado, I., "Programmable Coding Techniques for Semiconductor/Acoustic Surface Wave Devices," *Proceedings IEEE 1972 Region Six Conference*, p 96, 1972

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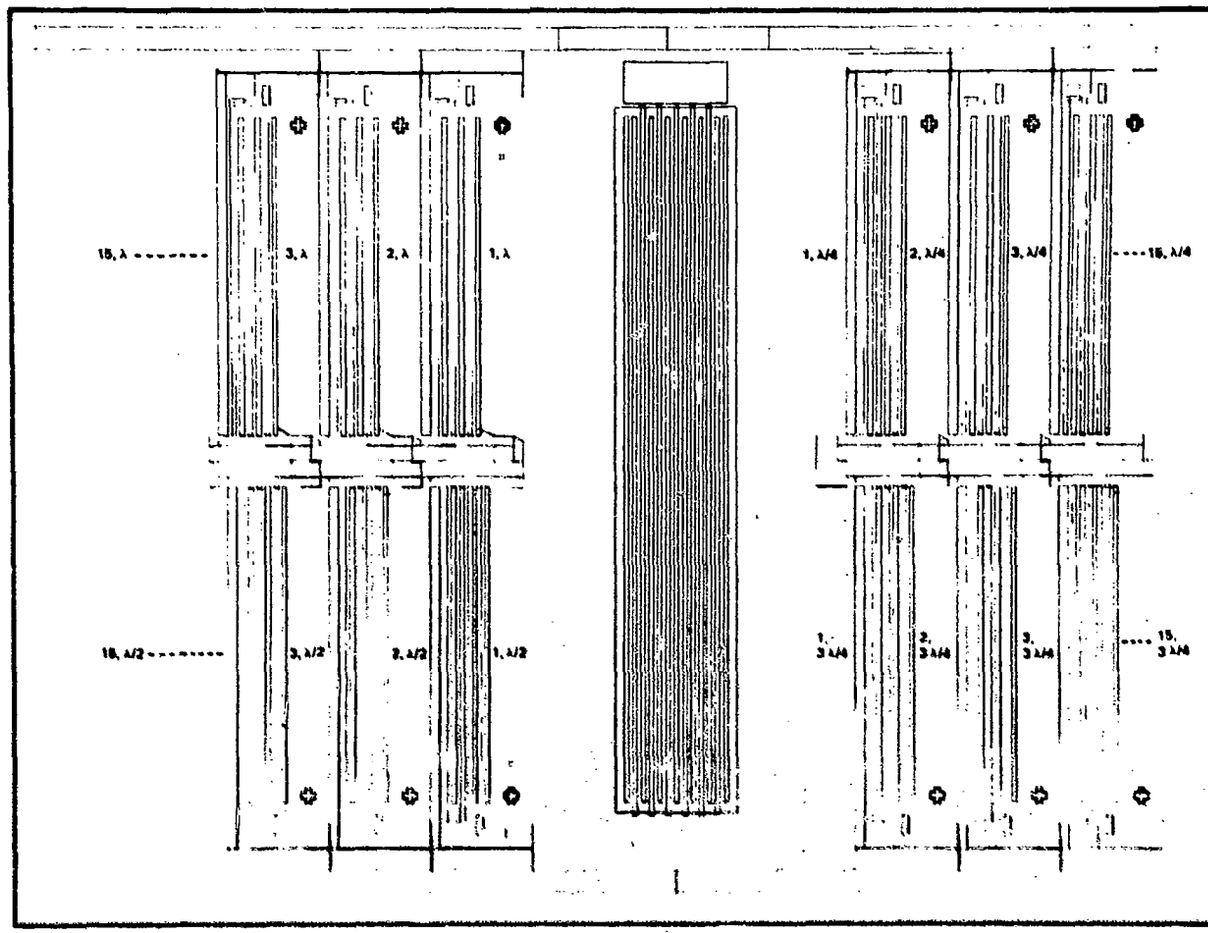

Figure 1. CAD printout of ZnO/MOSFET programmable correlator– interdigital transducer structure in center and three MOSFET tap structures in each of four quadrants.

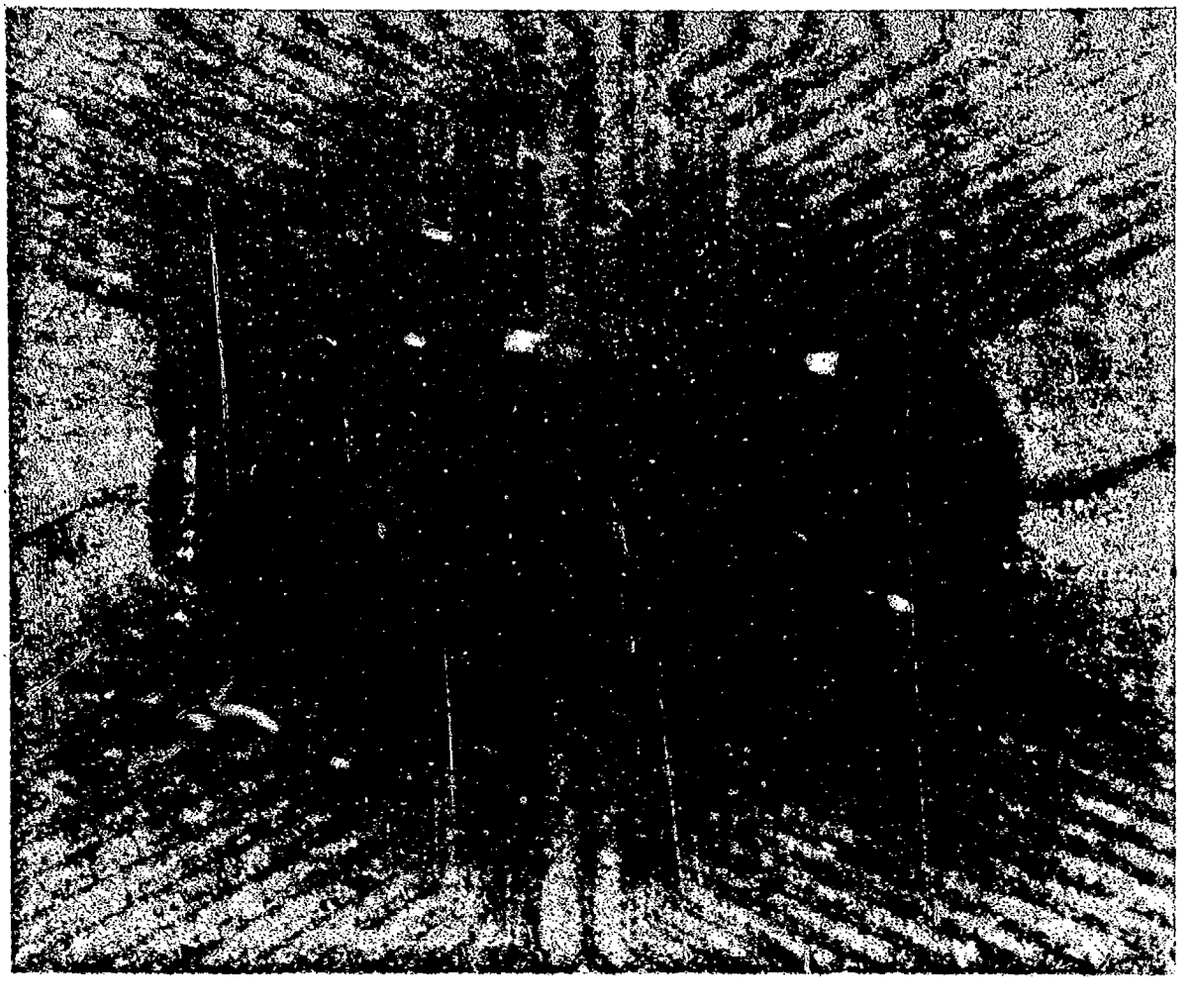

Figure 2. Fifteen-bit quadriphase programmable correlator

Figure 3. Output response of a 15-bit MOSFET tap structure to an impulse at the ZnO transducer.

IR Photocathodes for Navy Detection Systems

The goal of this program is the development of a photocathode material with a long-wavelength threshold of 2 μm. Such a photocathode could be used along with a 1.54-μm laser to make active ranging systems that would be safe to the eye. In addition, many passive surveillance systems would be improved by the ability of a 2-μm cathode to harness the large amount of nightglow radiation emitted continually by the upper atmosphere. (It is not generally appreciated how intense this nighttime radiation is, because of its weakness in the visible part of the spectrum. It is so strong in the near infrared, however, that if it were visible to the eye, only the brightest stars could be seen against its background.) In the work described here, the infrared radiation excites electrons in a sample of p-type GaSb. The electrons are then induced to tunnel into vacuum by an intense electric field applied to the surface of the semiconductor. The high fields are produced by etching the sample to a fine point of approximately 1 μm in radius.

In FY73 the tunneling current was investigated at room temperature from points of GaSb mounted in an ultrahigh vacuum system. The I-V characteristic has been measured and found to obey a Fowler-Nordheim emission characteristic as expected. By fitting a Fowler-Nordheim curve to the data points, a work function of $4.13(R)^{-2/3}$ eV was determined. R is the tip radius in μm and cannot be exactly determined, although scanning electron microscope examinations indicate radii in the 1-5-μm range. No change in this field emission current could be produced upon irradiation of the sample with 6.5 mW (3.20×10^{18} photons/sec) of 0.633-μm red light from a He-Ne laser. The probable reason for this null result is that the thermally generated carriers outnumber the optically generated carriers in GaSb at room temperature. A low-temperature field emission apparatus has therefore been designed for repeating the I-V measurements at 77K.

Two important qualitative observations were made during the course of these measurements. The first is that the maximum current that can be drawn from a single tip is on the order of 10^{-8} ampere. Currents above this value are accompanied by an arc which is sustained in the ultrahigh vacuum environment by evaporation of the GaSb. The arc is most likely initiated by resistive heating of the sample and eventually destroys the tip. Although this problem is present even with metallic field emission points, it is more severe with semiconductor materials, because of their lower melting temperatures. (Tungsten melts at 3653K; GaSb melts at 1001K.)

The second important observation was of erratic jumps on the order of 50 to 100% in the field emission current at a fixed voltage. Since this current depends in a very rapid exponential manner on the shape and work function of the tip, unobservably small changes in these parameters are most likely responsible for these instabilities. Absorption of gas molecules onto the tip with an accompanying change in work function will be investigated in the coming fiscal year in an effort to reduce the noise to its fundamental shot noise limit.

ZR021.03
(NELC Z175)

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Surface Barrier Physics

During FY73 work was initiated on the surface properties and the physics of surface barriers of narrow-bandgap semiconducting III-V compound films deposited on insulating substrates. Specific emphasis was placed on the photoelectronic properties of indium antimonide (InSb) and indium antimonide indium arsenide ($InSb_xAs_{1-x}$) solid solution layers.

Surface photovoltage measurements made as functions of wavelength and temperature on n- and p-type InSb in the carrier concentration range of 8.9×10^{13} to 1.0×10^{18} cm^{-3} using an MIS (metal-insulator-semiconductor) sandwich employing for the dielectric an anodically formed layer of In_2O_3 indicate that, when cooled in the dark, the surface of the n-type material is near flat band whereas that of the p-type is depleted. Illumination with photons of energy in excess of ~ 1.5 eV leads to a shift of the surface potential to larger negative values as a result of optical activation of electrons from fast interfacial surface states to slow states near the InSb surface. It is concluded from theory, and supported by experiment, that surface trapping, as well as recombination, has considerable influence on the photovoltaic response of MOS (metal-oxide-semiconductor) infrared sensors.

The requirement for low-cost, reproducible, consistent-response detectors for infrared imaging sensors and arrays can be met by high-quality films of suitable III-V compound semiconductors. In addition, the indium arsenide antimonide system offers a potential for longer-wavelength photoresponse than is currently available. Progress is described toward the understanding of the preparation of these films and their properties.

The photoelectromagnetic (PEM) response of high-purity single-crystal n-type InSb has been measured over the temperature range 80 to 300 K. A comparison of the data with the results of a theoretical treatment of the PEM effect generalized to include bulk generation at arbitrary magnetic fields, gives values for the surface recombination velocity on this material as functions both of temperature and of surface preparation and includes the first reported observation of a negative PEM response due to the diffusion of carriers into recombination sites at the illuminated sample surface.

The temperature-dependent photoconductive and surface barrier photovoltaic spectral responses of $InAs_{0.07}Sb_{0.93}$ films with an impurity density $\sim 5.5 \times 10^{15}$ cm^{-3}, grown by liquid-phase microzone crystallization, are shown to be functions of their fundamental energy bandgaps shifted to values lower than those of InSb. From charge carrier transport measurements their absolute zero bandgap is calculated as $\epsilon_{go} = 0.197$ eV, in good agreement with theory. In contrast with previously reported data on $InAs_xSb_{1-x}$ solid solution bulk and single-crystal layers, the electron mobility of $InAs_{0.07}Sb_{0.93}$ films increases with decreasing temperature, reaching a value of $\sim 1.32 \times 10^5$ cm^2/Vs at 77 K.

This work was directed primarily towards achieving better understanding of the surface and surface barrier properties of III-V compound films whose use is contemplated for simple, low-cost infrared imaging sensors and imaging arrays.

PUBLICATIONS

Lile, D. L., "Surface Photovoltage and Internal Photoemission at the Anodized InSb Surface," *Surface Science, 34,* 337, 1973

Wieder, H. H., and Clawson, A. R., "Photo-Electronic Properties of $InAs_{0.07}Sb_{0.93}$ Films," *Thin Solid Films, 15,* 217, 1973

Lile, D. L., "The Generalized Photoelectromagnetic Effect in Semiconductors," *Physical Review,* 20 April 1973

During 1973, H. H. Wieder was elected chairman of the Thin Film Division, American Vacuum Society. He also served as one of two U.S. representatives on the International Thin Film Committee, IUPAP, Venice, Italy (May 1973).

ZR011.02
(NELC Z176)

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Surface Wave Spread–Spectrum Transceiver

Engineering and fabrication of a small, hand-held, spread-spectrum transceiver which had largely been developed under another problem were accomplished under Z231 in FY73.

The transceiver employs PCM with six bits of quantization. Information is conveyed via a surface wave device whose code (11-bit Barker) is transmitted via pulse position modulation.

Acoustic technology offers significant advantages over electronic. Sound velocity is five orders of magnitude less than the speed of light, and acoustic devices for a given frequency are accordingly smaller than their em counterparts. An acoustic wave resonator is typically 100000 times smaller than an em resonator operating at the same frequency. An acoustic delay line can achieve 1 microsecond of delay in 3 centimeters of crystal—an em line would require 300 meters.

The results of this project were presented at the 1973 Spread Spectrum Symposium held at NELC in March 1973 and will appear in the conference proceedings. Details of the design can be obtained from the TD described below.

PUBLICATION

Schiff, M. L., and Dilley, D. M., "Surface Acoustic Wave Spread Spectrum Modem," NELC Technical Document 248, 18 April 1973

(NELC Z231)

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Narrowband Detectors

Laser communication and detection applications with high background conditions require very narrow receiver (or detector) spectral bandwidths for good signal-to-noise ratio. This is so because the background—for example, the sky or illuminated earth—radiates a broad continuum which contributes noise to the receiver. Since the laser radiates an extremely narrowband signal, reduction of the receiver spectral bandwidth proportionally reduces the background noise while leaving the laser signal unaffected.

Conflicting bandwidth and field-of-view requirements of laser communication and detection systems may be met by using rare-earth "quantum counters." NELC is investigating trivalent erbium in a host crystal of lanthanum trifluoride.

The conventional method of narrowing visible laser receiver bandwidth uses multilayer interference filters. In some systems a wide field of view is also necessary and this requirement is in conflict with that for narrow bandwidth because the bandwidth of interference filters increases rapidly with increasing field of view.

It is possible to achieve very narrow spectral bandwidth while preserving wide field of view by using rare-earth-activated "quantum counters." Spectral bandwidths of 1 Å or less have been demonstrated. The objectives of this program are to increase the sensitivity and to improve the wavelength selectability of this type of detector.

Quantum counters of this type make use of the very sharp spectral properties of transitions between the energy levels of rare-earth ions in crystals. Since only signal radiation of a definite wavelength is able to excite a given transition, fluorescent output from a level excited by such a transition is a measure of how many signal quanta have been absorbed.

During FY73 a survey was made to find a quantum-counting scheme suitable for use with the 5145-Å emission from the argon-ion laser. The candidate scheme selected for investigation is trivalent erbium in a host crystal of lanthanum trifluoride ($La_{1-x}Er_xF_3$, where x is the mole fraction of Er^{3+}).

Single-crystal samples of $La_{1-x}Er_xF_3$ were purchased with x-values ranging from 0.001 to 0.01. The samples were studied spectroscopically by use of an argon-ion laser and pumped with a tungsten lamp to determine their suitability as 5145-Å quantum counters, with the following results.

There is a mismatch of several angstroms between the laser and the quantum-counting transition. Even so, the laser excited an excessive amount of anti-Stokes fluorescence at the quantum counter output wavelength, even with no pumping radiation. Therefore, quantum counter action could not be observed.

The next phase of this program will be to attempt to shift the Er^{3+} transition into coincidence with the laser emission and, if successful, to measure the effectiveness of this scheme for a laser detector.

ZR021.03
(NELC Z178)

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Kinetics and Effects of Hydrogen at the $Si-SiO_2$ Interphase

Rigid control of the semiconductor-dielectric interface is fundamental to the consistent production of integrated circuits in high yield. The processes by which the $Si-SiO_2$ interface is formed were reviewed theoretically and experimentally, and an improved process for production of uniform interfaces was brought to light.

Technical requirements for Naval surveillance, command control, and communication systems demand an ever-increasing effort in integrated circuit technology. The specific objective of this research is to produce a high-quality silicon-silicon oxide interphase for the MOS device. We prefer the term "interphase" to "interface" because layers adjacent to the plane of separation differ in chemical composition from those farther away. The thickness of the interphase extends to about 20 Å.

In the course of the detailed review of available literature we concluded that there is a relationship between the material (silicon), the process of SiO_2 formation, and the intended use (device). These factors cannot be treated separately. We also noted that the quality of the silicon-silicon oxide system, expressed as the surface state's density and recombination velocity, depends on rate of deposition, which—in turn—depends on temperature acting as a driving force. Temperatures as high as 1200°C are usually employed in chemical oxidation of silicon wafers. Temperatures can be considerably lowered, if, instead of chemical attack by gaseous oxygen, both silicon and oxygen are supplied from an outside source and reacted on the silicon surface. This process, "vapor phase deposition," yields SiO_2 deposits at temperatures as low as 300°C. Furthermore, it offers a convenient way to investigate the effect of temperature and feed composition on product quality.

High-quality Si/SiO_2 interphase has been obtained by exposing Si-surface to a mixture of SiH_4 and O_2 in N_2 as the carrier gas. In the course of this reaction atomic hydrogen is generated, which, by subsequent reaction with SiO_2, produces an unbounded silicon, resulting in high value of surface state density. In evaluating the effect of hydrogen, it is helpful to compare the interphase properties as produced in the presence and absence of hydrogen. It appears that vapor phase deposition is ideally suited for this purpose. Substitution of $Si(O\text{-}R)_4$ for SiH_4 ((-O-R) is an organic radical containing oxygen), for example, will produce SiO_2 films at 500°C with no atomic hydrogen present. Thus, the effect of hydrogen can be immediately illustrated.

To assure rigid control of process variables such as temperature, composition, and pressure and to provide means for visual inspection, a flow-type reactor has been designed and built. This reactor will provide greater versatility and better process control. What is equally important, it can be adapted for pilot plant production.

In the course of experimental work, low-temperature deposition of SiO_2 layers was obtained. Scanning electron microscopy gave indication of layers of uniform character.

This work served as a basis for the formulation of research projects leading to better understanding of phenomena taking place at—or in the vicinity of—the solid-solid interface. It also served as a basis for the design of other reactors currently used for the deposition of silicon nitride.

ZR011.02
(NELC Z186)

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Microwave Integrated Circuits for Millimeter Wavelengths

In order to exploit the potential use of the millimeter-wave portion of the spectrum for Navy systems, a complement of plumbing and hardware of proved efficiency and reliability must be available to the design engineer. To this end the millimeter equivalents of microstrip transmission lines fabricated from both quartz and irradiated polyolefin were investigated with some success. It was necessary to innovate and validate many circuit elements in the test fixture for this purpose.

This task's objective has been to determine and demonstrate the feasibility of microwave integrated circuits (MICs) for use at millimeter wavelengths. The inherent advantages of small size, ruggedness, and reliability are critically important to the fulfillment of naval systems requirements in the millimeter bands. Specific requirements are indicated for enf covert communications and electronic-support-measures systems.

A fundamental problem in MIC design and development is transfer of rf energy between various circuit elements. Some form of integrable transmission line, or waveguide, must be used which is suitable in terms of size and ease of fabrication, while at the same time offering satisfactory performance in terms of the usual criteria applicable to rf transmission lines. The chosen approach focused on the use of microstrip, a type of transmission line previously used with considerable success at lower microwave frequencies, as a basis for hybrid MIC development.

Suitable substrate materials and coatings also had to be selected. In this regard, a two-pronged approach was taken, considering fused quartz and irradiated polyolefin as promising candidates. Some degree of success has been achieved with each of these substrate materials, and at this point neither can be cited as clearly superior to the other. Each has its own peculiar advantages and disadvantages. Although other researchers have reported experiments with fused quartz substrates in the frequency range of interest, little or no work appears to have been done elsewhere at these frequencies with the less expensive and more rugged plastic substrate materials such as irradiated polyolefin.

A general lack of commercially available hardware for circuit mounting and interconnecting necessitated in-house development of these items for laboratory use in the millimeter bands. Two types of waveguide-to-microstrip transitions were developed for use in the 26.5-40-GHz band. Both types utilize transformer sections of the single-ridge variety to provide an impedance match to 50-ohm microstrip. Initial design efforts concentrated on a stepped-ridge configuration containing five quarter-wave sections to produce a Chebichev response over the full 26.5-40-GHz band. Satisfactory performance was achieved. For more rigorously demanding laboratory evaluations of critical circuits, however, a type of transition offering a superior level of performance was deemed desirable. A unit was designed and fabricated using a relatively long cosine tapered-ridge section. Results were sufficiently encouraging to justify the inherent difficulty of machining the required transcendental contour. Several more of the units were subsequently fabricated to aid in connecting experimental MICs to external test equipment.

During the investigations, a novel type of variable-impedance transition was developed for matching coaxial cable to microstrip. Also developed was a microstrip circuit test jig to facilitate safe and rapid mounting and demounting of MICs for test purposes.

Work has progressed to the extent that groundwork has been laid and a suitable basis has been established for development of components and circuits directly applicable to naval systems requirements.

ZR021.03
(NELC Z188)

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Solid-State Low-Noise Microwave Amplifiers

In support of the effort to improve low-noise microwave amplifiers, a materials program to improve the characteristics of the devices used in these equipments was instituted, focused on indium phosphide and phosphorus-doped indium arsenide.

This program, which began in April 1973, is a combined effort of the Microwave Technology Division and the Electronic Materials Science Division to develop solid-state devices and circuits for use in low-noise microwave amplifiers for EW and radar. Two types of devices are under consideration:

1. Field effect transistors (FETs) for frequencies below 10 GHz, and
2. Transferred electron diode amplifiers (TEAs) for frequencies above 10 GHz.

Microwave FETs have been reported with low noise characteristics using gallium arsenide (GaAs). One disadvantage of this material is poor yield per wafer, resulting from the micron and submicron widths required for microwave operation. Materials having higher carrier mobility, such as indium arsenide (InAs), will be used in this program to allow larger dimensions and subsequently higher yield.

TEA diodes exhibiting the lowest reported noise are currently being produced by two research organizations in England. These diodes use indium phosphide (InP). This material is difficult to work with, however, and the diodes are not available here. TEA diodes in this country are all developed from GaAs. The approach in this program is to substitute phosphorus atoms for arsenic atoms in InAs to obtain indium arsenide phosphide (InAsP) material, which should, at some degree of substitution, exhibit the energy band structure required for the transferred electron effect.

Since the inception of this program, material and microwave properties of InP have been reviewed and a technical note has been written about them. Programs have been written for computer-aided design using transistor scattering parameters, and microstrip bias circuits are presently being developed. Commercial GaAs FETs have been ordered from the single commercial source in the U.S. (Fairchild) presently marketing such devices.

PUBLICATION

Lile, D. L., "The III-V Compound InP and its Device Applications," NELC Technical Note 2409, 21 June 1973

ZR021.02
(NELC Z189)

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Optical Multiplexing (Towed Acoustic Array)

The purpose of this joint effort between NELC and NUC is to investigate the feasibility and utility of using fiber optics for data transfer in a towed sonar array. As an alternative approach to coaxial electrical cable, the newly developing, low-loss (2 dB/km for a single fiber) fiber optic cable offers important advantages to undersea cabling and information transfer. The principal ones are very large bandwidth for a given cross section, light weight, and immunity from electrical interference.

During the first phase of the program ending in June 1972, a representative towed array system was planned and analyzed. Multiplexing (time division) electronics components were teste and synthesized. Light-emitting-diode sources and optical detectors (photomultipliers, PIN diodes, and avalanche photodiodes) were evaluated with matching electronics interfaces. Experimental fiber optic bundles were ordered from Corning Glass Works to be 1000 feet in length and have optical loss of less than 33 dB. Investigations were begun using conventional cabling techniques to incorporate commercial, high-loss fiber bundles into experimental cables with strength and electrical-power-bearing members. General environmental testing of commercial fibers was undertaken. Investigation of optical penetrators for pressure hulls was begun in context of bringing one or many (multiplexed) channels through a hull, minimizing the number and size of required openings.

In FY73 a bench system was completed including analog-to-digital conversion, 64 channels of multiplex and digital encoding, optical transmission, demultiplex, and digital-to-analog conversion. In addition, a wet array package containing three hydrophone channels, signal conditioning, and a multiplex scanner-encoder was completed for use with the tow cable when it is developed. The bit rate for these, governed by the electronics, ranged up to 2 Mbit/sec; bit error rates over 150 feet of high-loss fibers and over 1000 feet of low-loss fibers were less than 10^{-7} bit/sec. Three experimental 1000-foot fiber bundles were evaluated. Two achieved the loss objectives, and the bit rates transmitted were consistent with those reported in the literature—namely, about 50 Mbits/sec-km with an incoherent source. Repeaters are feasible, but the emphasis was on maximum length/minimum loss to eliminate or at least minimize their use.

The direct application of some present cable methods produced three 200-foot experimental versions incorporating commercial glass fibers. The configurations around the fiber bundles were (1) twisted steel wires, (2) knit steel wires, and (3) knitted plastic PRD-49. These attempts caused excessive fiber breakage, and, although conventional techniques were hardly exhausted, it seems evident that a systematic study and substantial development effort will be required to produce long (several kilometers), low-loss, fiber optic undersea cables.

The testing of commercial, plastic-coated fiber optic bundles showed them to meet a wide range of mechanical and environmental requirements. Further, jacketing them for short-length applications, such as aboard ships or aircraft, appears well within the present cabling techniques.

Finally, the optical feedthroughs were tested in several configurations. Not unexpectedly, solid plastic, glass, or silica rods fitted into a standard compression gland penetrator withstood pressure tests in excess of 10 000 psi (in some cases 20 000 psi) and provided good optical transmission. Spatial multiplexing is feasible with graded-index rods, and a high-speed driver circuit (50 Mbits/sec) LED driver was developed for time division multiplexing.

This program has directly or indirectly stimulated the following programs in fiber optics communications:

- Fiber Optics Radiation
- Fiber Optic EMP
- Secure Fiber Optics Communication
- Fiber Optics CCTV Link
- AN/PPS-18 Marine Radar
- Fiber Optics Evaluation (for Undersea Cables)

ZF61.212
(NELC Z242)

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Advanced Integrated Materials Power Supply

Electronic power supplies are rapidly becoming the critical element in electronic system design through their reluctance to become integrated. IC regulators and power transformers and power inductors cannot presently be included in the silicon integration. NELC has demonstrated, however, that these parts can be produced as parts of integrated circuits, and the 3-year IR/IED program has reached the point at which probability of success in fabricating a complete power supply circuit as a single integrated part is high.

Progress in FY73 enables NELC to envision the fabrication in FY74 of a complete power supply circuit as a single integrated part—with MTBF on the order of 10^6 hours.

The reliability factor is the main reason for the criticality of the power supply in electronic systems. A power supply is considered outstanding today if it has 100 000 hours calculated MTBF. The objective for the near future is much higher, and integration is recognized as the way to achieve it.

FY73

The following technical progress was registered in FY73:

1. Magnetic devices were batch processed by the screen-and-fire process. Shell-type inductors were built with over 40 turns and over 5-μH inductance with Q factors greater than 25 at currents to 2 amperes. It is believed that shell-type transformers can be made by the same techniques.

Physical dimensions are microminiature—80 mils square for the above inductor. Thus, volumetric efficiency is high—more than 1 kW reactive per cubic inch at 200 kHz [Ref 1].

2. The high-dielectric-constant material long used in ceramic capacitors was further developed to produce screenable inks which can be used in combined screen-and-fire processing with the magnetics, thereby including capacitive energy storage with magnetic energy storage and transformer isolation in a single part.

3. Experimental parts of the combined nature (L-C) were built. Excellent results were obtained with the magnetics (μ = 1500), but dielectric constants need improving (the first experimental ink fired with the magnetics in the same device produced a dielectric constant on the order of 65). The inks were prepared with titanate dielectric particles in a glass binder, and the particles were too small. Larger particles will increase the dielectric constant to above 1000 and thereby serve to maintain reasonable microminiaturization [Ref 2].

4. Amorphous semiconductors fabricated by processes compatible with screen-and-fire techniques were investigated and are being developed. Investigations to date indicate a reasonable chance of success in regard to electrical function and physical fabrication [Ref 3].

FY74

NELC expects to reduce to practice the total integration of electronic power supplies including transformers and energy storage functions on a continuing IR/IED program in FY74.

Switching regulator circuits for power levels from 500 mW to 100 W are expected to be achieved, including active semiconductor functions as well as energy storage and dc isolation.

In reliability, the integrated electronic power supply is expected to be superior to current power supplies by at least an order of magnitude—with MTBF on the order of 10^6 hours.

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1. "The Monolithic Ceramic Chip Inductor," San Fernando Electric Company
2. Weekly Status Report, 14 May 1973, Autonetics Contract N00244-73-D-0281
3. "Electronic Materials for Components in Power Supply Systems (A State-of-the-Art Review)," by J. D. Mackenzie, Department of Engineering and Applied Science, UCLA

ZF61.512
(NELC Z251)

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Tuned Hf Antenna System for Small, High-Speed Ships

The Navy is putting a good deal of emphasis on developing high-speed, limited-size surface craft. The several types--including hydrofoil, air-cushion craft, and fast patrol craft--have significant communications needs, including hf.

The antenna systems available for hf are not suitable, mainly from the standpoints of size and efficiency. The common approach for most craft of this type is a 35-foot whip antenna with a base tuner. This antenna often interferes with other operations, such as vertical replenishment, and frequently compromises them unacceptably.

Similar problems occur on larger ships, particularly with increased air operations, and a strong need exists for a new approach to the hf requirements for tuned antennas.

The effort during FY73 was to develop a design approach for a tuned hf antenna system for small, high-speed ships such that two transceivers can simultaneously use one antenna in the 2-30-MHz frequency range. A single antenna would be developed--modeling techniques would be used--that would successfully operate over the 2-30-MHz range. Based on the antenna data, a tuner/coupler/filter (multicoupler) network design approach would be developed along with necessary preprogrammed read-only-memory control logic for remote control of the multicoupler. A breadboard model of the network would be constructed and bench tested for power, efficiency, bandpass, and electromagnetic compatibility (EMC). Then the entire breadboard system would be put together and tested full scale in a ship-like electrical environment at the NELC antenna test facility to prove effectiveness of design.

An antenna was designed and tested via modeling techniques. A three-channel multicoupler was rebuilt from a previous project to conform to system criteria. To achieve such a wide-bandwidth system, the multicoupler's combiner and matching network were tailored to the antenna's impedance.

An antenna impedance simulator was built and connected to the multicoupler. The entire system was then tested with the model antenna impedances used as the multicoupler load. Extensive high-power tests as well as EMC tests were performed. All tests were successfully completed.

A mechanical design and analysis of the weight and moment properties of the new antenna were performed. Ship stability will be affected to a small degree.

A suitable remote control unit for the multicoupler was designed, built, and tested. Initial indications are that a ROM system is suitable for automatic tuning.

FOLLOW-ON

Follow-on is proposed for FY74 to determine the EMC/radiation hazard situation.

PUBLICATIONS

An NELC Technical Report on this project will be written and published in FY74.

ZF61.512
(NELC Z254)

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Charge-Coupled Device (CCD) Bulk Storage Memory

CCD is an advanced memory technology based upon the capacitor. It may be the answer to the Navy's need for very-high-density storage equipment.

In the sixties a revolution took place in information processing. Vast increases in volume of communications and in computing power were made. Computers became a good deal faster and easier to converse with.

Paper printouts, magnetic tapes, and disks used to store data are bulky, relatively slow, and unsatisfactory for many other reasons. Requirements for high-density storage equipment—that is, equipment with storage capacity in the millions of bits per square inch—can only increase, so there is a critical need for new and different techniques of data storage. On the basis of research performed in FY72 under Z169 (Advanced Memories Technology), the area of Charge-Coupled-Device (CCD) technology was selected for further exploratory development. An analytical and experimental program in charge-coupled devices was set up, aimed at the implementation of a CCD bulk memory for possible Navy application.

The great attractiveness of a CCD lies in its structural simplicity. Basically, the device is a linear row of capacitors, along which a charge is passed by virtue of clock voltages applied to the capacitors in a given sequence.

The analytical portion of the program has provided a fundamental understanding of (1) the distribution of electrical charges and the factors that influence the time variation of charge distribution in the semiconductor dielectric interface used in charge-coupled devices, (2) the parameters influencing the properties of the silicon-silicon dioxide system and their effect on device performance in terms of charge transfer speed and efficiency, and (3) the capabilities and limitations of CCDs in memory applications with respect to system applications. In addition, a design concept for a CCD bulk storage unit was formulated, embodying a cabinet 12" H x 19" W x 20" D with room for 31 cards, 7.5" square, of which two to four cards would be used for memory control and the remainder for memory.

Assuming an 8k chip in a single dual in-line package, each card could accommodate seventy-five 16-pin packages. This would result in a data storage capability of about 8 million bits (1M bytes) in about 3 cubic feet of space, with a power requirement of about 30 watts and an output rate of millions of words per second. Data access time would be on the order of 100 microseconds. The storage capacity of the cabinet could be increased to 32 million bits via more sophisticated packaging techniques.

A simple test and demonstration unit was designed to verify CCD characteristics. It is compatible with the CP-642B computer and incorporates memory control and interface functions. FY74 plan calls for the design and testing of novel CCD structures and memory system architecture studies.

PUBLICATIONS

Symanski, J. J., "Advanced Memory Technologies: A Progress Report," NELC Technical Report 1876, 31 May 1973

ZF61.212.
(NELC Z255)

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225-6515

Switching Regulator Technology

This program addressed the inherent characteristics of switching regulators and the performance of commercially available units with the purpose of assisting the introduction of this class of regulated power supplies into Navy systems applications.

This task is concerned with avoidance of problems in the selection, procurement, and application of switching mode voltage regulators in electronic equipment. It is expected that this type of regulator will be used to an increasing extent in military electronics due to increasing availability as a system component and favorable impact on system figure of merit. This type of power supply exhibits a class of problems different from those of conventional dissipative regulators. The objective of the task is to define these problems, through analysis and testing, and suggest how they can be avoided in system design by proper selection, procurement, and application. Only switching regulators that convert ac line voltage directly to dc without use of transformers and then perform power conversion at higher than line frequency are considered.

The FY73 program verified the system impact of this class of switching regulators, procured regulators for evaluation, and ran evaluation tests. In addition, control loop characteristics were modeled as an aid in evaluation, as a method of classifying the regulators, and as a factor in control loop stability within a system. A patent search was conducted. The final report is in preparation.

The system impact of switching regulators was confirmed by using catalog item dissipative and switching regulators from the same manufacturer in typical tradeoff studies of power systems. It was shown that the switching regulators themselves offer worthwhile advantages, such as a four-times reduction in weight. This advantage of switching regulators is enhanced when they are used in systems to take full advantage of their characteristics, and a system leverage is obtained for the whole power system that can result in a 13.5 improvement factor for the power system contribution to weight. Switching regulator characteristics also considerably ease the burden of achieving reliability through redundancy. Power can be obtained from redundant sources or power bus reliability with redundant power supplies can be improved with much smaller impact on system figure of merit with switching regulators than with dissipative regulators.

An effort was made to identify every vendor in the United States making a catalog item switching regulator that might be used in an item of military electronic equipment. Twenty-nine models of switching regulators were ordered from the 15 vendors so identified. Several vendors were not able to deliver the regulators at all, or were unable to deliver on time or for the reported price. This indicated, as did discussions with knowledgeable people, that power supply vendors competent in the design and manufacturer of dissipative regulators were finding it more difficult than they had expected to reduce switching regulators to a product. Evaluation of the procured switching regulators concentrated on characteristics not usually found on specification sheets but important in system design. Many anomalies were found due to the nonlinear characteristics of some of the designs.

Regulators differ in control loop stability. Control loop characteristics were investigated and an attempt made to use them to classify the regulators in a way that would point to the inherent weakness and strength of each configuration. This information is useful in compensating for weaknesses in a given configuration and serves as a framework for design, design review, and consulting activity. The approach taken was to describe the characteristics on a phase-plane plot on which reference voltage and output voltage derivatives are plotted against reference voltage and output voltage. Plots generated by a computer using a nonlinear analysis program were used that displayed the effects of transistor switch storage time, comparator hysteresis, saturation characteristics, and signal propagation delay. A patent search was conducted yielding 55 patents to serve, along with the procured power supplies, as input material in developing this type of classification methodology.

The technical knowledge brought to and derived from this task provided technical support to the following tasks:

- A presentation on "Power Supplies—Technology Trends and Problems" at the November 1972 Navy Laboratories Briefings for Industry, resulting in an invitation to present a paper at one of the IEEE em compatibility conferences on the interaction of switching regulators with system em interference filters.
- Consulting to the NAVSEC AEGIS Radar Project Office during the development of the signal processor power supplies and the phase shifter driver power supplies on the AN/SPY-1 Radar, resulting in a $96 000 net cost savings.
- System studies, hardware, and technical briefing on the NAVELEX Advanced Modular Uhf Transmitter/Receiver Program (R201).
- Inputs and comments on the Power Sources Technological Application Area of the Electron Device Technological Coordinating Paper (NAVELEX).
- Stability Analysis of the 5V-1A ac/dc input power supply in a Standard Hardware Program type 1C module (NAVELEX).

PUBLICATIONS

Foutz, J., "Selection, Procurement and Application of Switching Voltage Regulators in Electronic Equipment," NELC Technical Note (in preparation)

ZF61.512
(NELC Z260)

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CMOS Technology

CMOS (complementary metal-oxide-semiconductor) processing was added to NELC's microelectronics capability in FY73. A complex logic circuit was the demonstration vehicle. The achievement of near-theoretical response in the produced circuit demonstrates satisfactory process understanding and control.

A technological base was developed at NELC in complementary MOS (CMOS) for applications requiring high speed and low power consumption along with a good degree of large-scale integration (LSI).

A National Security Agency universal logic function, the "Banville Logic Circuit," was mechanized by use of a combination of six different CMOS cells. The resultant LSI chip is used as much as a generator of variable and fixed logic sequences for coding purposes as it is used as a process test structure. The design principles incorporated in the CMOS cells were analyzed for accuracy via the latest in computer-aided-design (CAD) techniques. A computer transient analysis program called MOSTRAN was used to simulate the dynamic performance of the circuit. The partitioning of the logic function into the CMOS cells, the cell layout, and ultimately the chip configuration were generated with the help of a computer-controlled interactive-graphics system which, as a peripheral display, permits easy and quick man-machine interaction from design concept through rough sketch to finished artwork. The system translates and records the data for the circuit pattern into a form suitable for driving other machines, such as a CALCOMP or Gerber plotter, used in the preparation of photomasks for the fabrication of LSI CMOS logic circuits.

During FY73, NELC gained valuable experience in CMOS technology. The Banville Logic Circuit, containing the equivalent of 90 gates, or 5×10^4–10^5 MOS transistors per square inch, was processed on a 0.075-by-0.075-inch chip. Its performance has satisfied the design requirements. Propagation delay of internal cells—such as static and dynamic shift registers, transmission gates, and D-type flip-flop—was found to be approximately 20 nsec. However, the worst-case path was exercised up to a 5-MHz data rate (see oscilloscope trace, fig 1). A completed circuit is shown on the photomicrograph (fig 2a). The breadboarding of four identical chips as a generator of coding sequences is illustrated in figure 3.

The correlation between the design goals and the measured dynamic performance of the finished chips was tightly related to the process controls that inexorably determine the practical capabilities needed to mechanize the cell itself. To this aim, a test device structure (see fig 2b)—that is, a second LSI chip—evolved from the selection of a set of electrical and physical parameters to be evaluated for process controls. The parameters which were monitored include channel carrier mobility (μ), lifetime (τ), interface state density (N_{ss}), oxide charge density (Q_{ss}), and flat band voltage (V_{fb}). The determination of the electrical characteristics is used to institute limits for controls of the process parameters. Oxide and interface state charge densities were measured by capacitance-voltage (c-v) techniques. The shift of the c-v curve after applying an electric field of 10^6 V/cm to the oxide at 300°C is used to evaluate N_{ss} and Q_{ss}. The monitoring of these and other parameters is needed to establish a "workable" technology. Table 1 summarizes the electrical data. A review of the data shows the effect of the "well or substrate" doping for the n-channel MOS transistors on breakdown voltage BV, threshold voltage V_{th}, mobility μ, and channel conductance G_m.

As a result of the present investigations, the availability of a workable CMOS technology within NELC has generated interest among system designers. At their request, the design and fabrication of a custom CMOS LSI function have been undertaken for incorporation into an advanced engineering module (ADM) to be evaluated in the third quarter of FY74.

Furthermore, a follow-on study was approved to pursue the development of silicon-gate CMOS and silicon-on-sapphire CMOS based on the results obtained to date.

PUBLICATIONS

An NELC technical document will report the results achieved.

ZF61.512
(NELC Z262)

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Lot	N-MOS				P-MOS			
	1		2		1 (galamar)		2 (semimetals)	
W/L	10	1	10	1	10	1	10	1
Well resistance (ohms/sq)	1150		210					
N_{ss}(charges/cm^2) measured by c-v techniques	$5x10^{10}$					$1.0x10^{11}$		$5x10^{10}$
Q_{ss}(charges/cm^2)	$5x10^{10}$				$5x10^{10}$			
BV (well-substrate)(V)	90		82					
BV (drain-well N-MOS) (drain-subst P-MOS)	35		13		45		50	
V_{th} (extrapolated)(V)	+0.3		4		-2.2		-2.0	
G_m (μmhos)	500	130	130	23	225	40	200	38
R_{on} (ohms) μ_{sat}(cm^2/V.sec)	800	5500 417	1000	$2.5.10^4$ 251	2500	$2.3.10^4$ 188	4000	$2.3.10^4$ 150

TABLE 1. CMOS TEST DEVICE ELECTRICAL RESULTS.

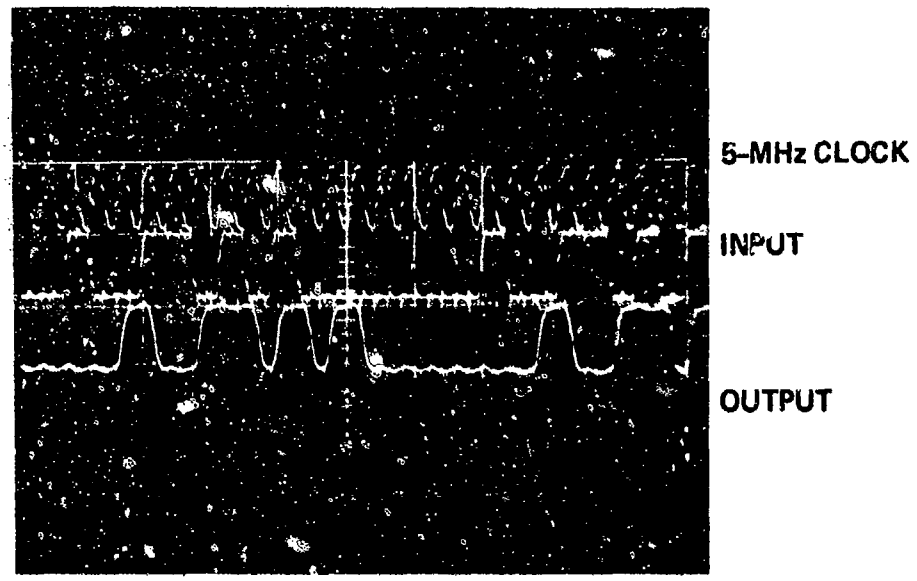

Figure 1. Performance of Banville Logic Circuit exercised at 5-MHz data rate.

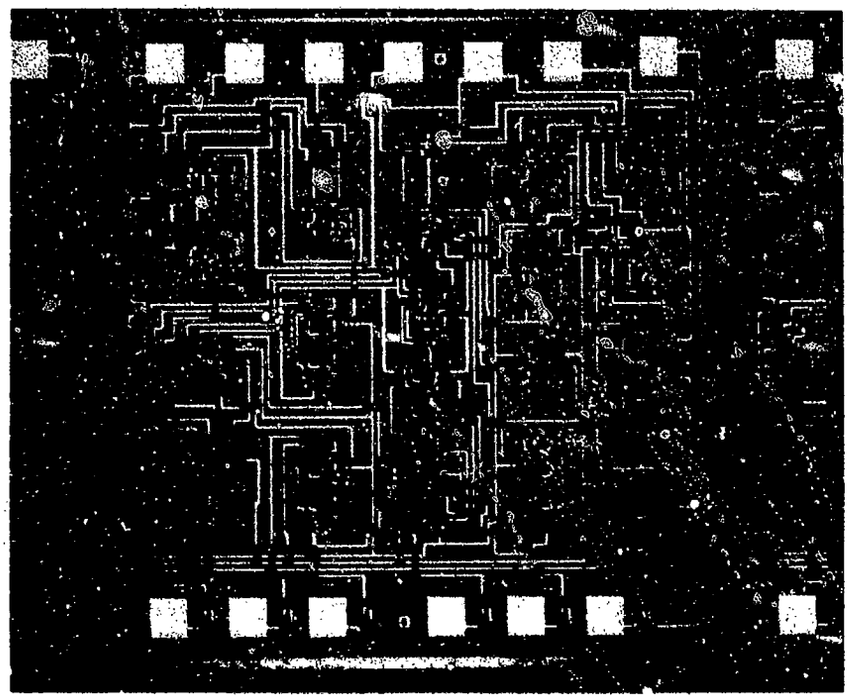

Figure 2a. CMOS test circuit containing NAND, NOR, and transmission gates, inverters, exclusive ORs, and static, dynamic and D-type flip-flops.

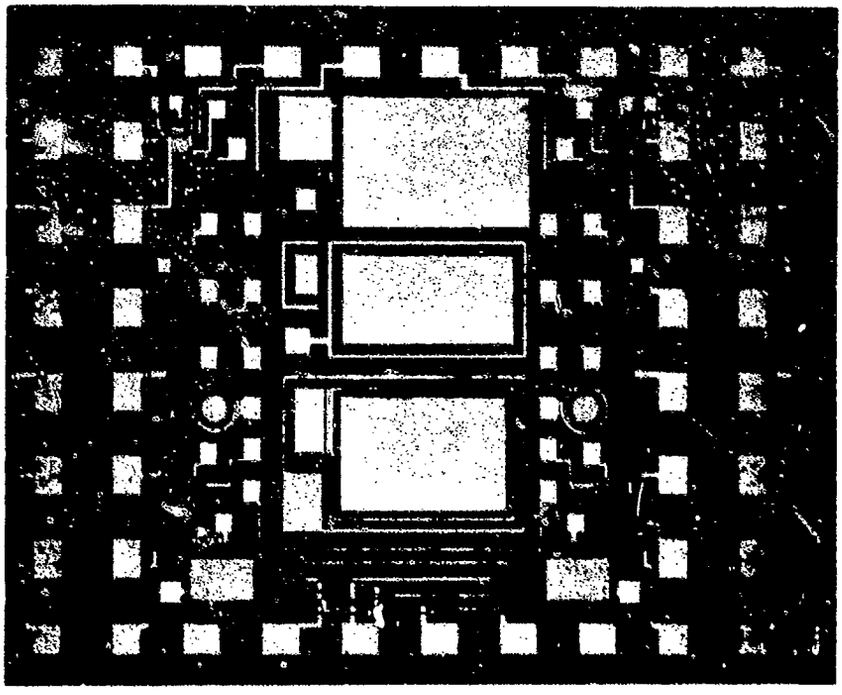

Figure 2b. CMOS test circuit containing PMOS and NMOS gate and field transistors, resistors, capacitors, channel stops, and diodes with field plates.

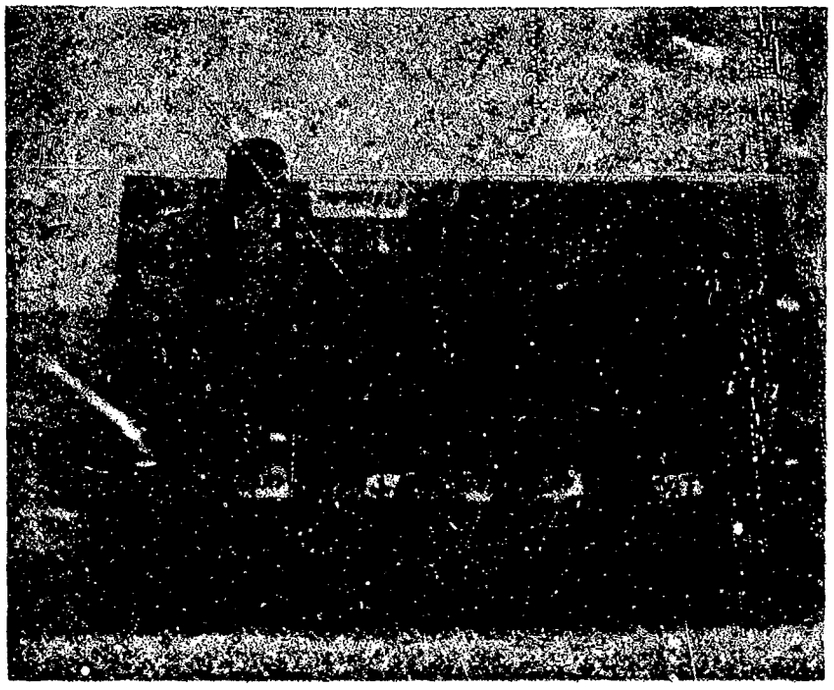

Figure 3a. Four identical chips used as a generator of coding sequences.

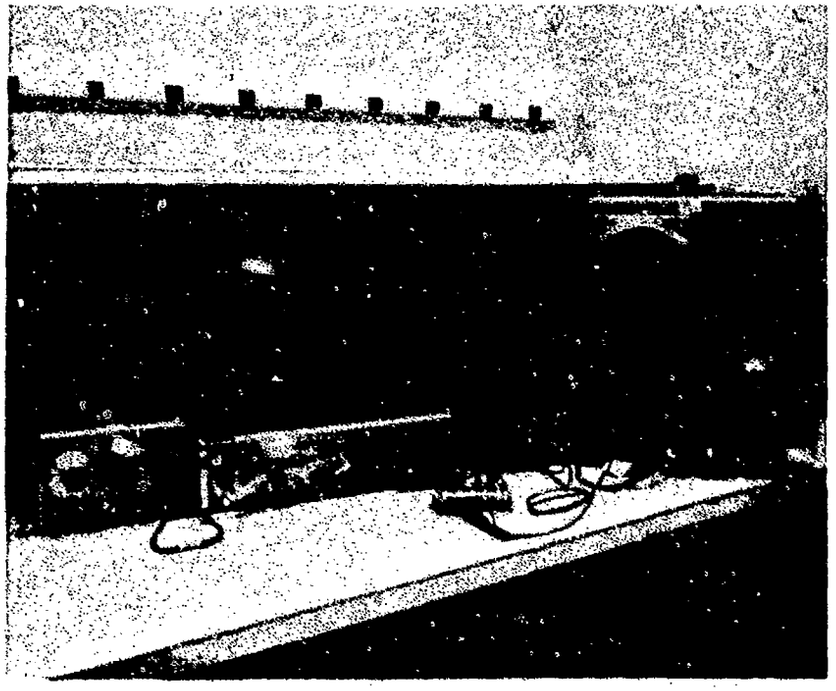

Figure 3b. Monitoring equipment

Digital Filters

Digital filters have long been considered desirable in the signal-processing portions of communications systems for the sake of accuracy and reliability, but prior to the advent of LSI were too unwieldy for most applications. With the solution of the size problem in sight, NELC designed and procured a versatile *programmable* digital filter in FY73 which can simulate the character of a specific computer-generated digital filter design and validate the design against the specific requirements. NELC also developed computer programs for determining the scaling coefficients needed to implement given filter designs.

Large-scale integration (LSI) has brought digital filter techniques closer to reality by providing a means by which the complex circuits required can be fabricated and employed in a moderate amount of space.

During FY73, NELC conducted an extensive investigation into implementation of digital filters using MOS/LSI circuits. This investigation included a thorough study into the technical background of digital filters to determine their operating characteristics. A contract was negotiated for the construction of a programmable digital filter to NELC specifications, using MOS/LSI components, for use as a hardware design aid. It contains eight elemental filter structures, A/D and D/A converters, a clock oscillator, a clock generator, a word timing generator, and power supplies. 122 MOS/LSI circuits are used to implement the converters and elemental filter structures. As examples of the programmability of the filter unit, the computational data word used in the internal processing of data in the digital filter is variable from 16 to 30 bits; the scaling coefficient loaded in the multipliers (which describe the filter response) is selectable to 12, 14, or 17 bits; and the clock (which is used to derive the sampling rate) is variable from 25 kHz to 1 MHz. Each of the elemental filter structures can be programmed for a maximum of two poles and two zeros, providing a "double precision" mode of operation, which means that the poles and zeros can be placed more accurately. Although requiring more hardware, the double-precision mode is an important feature in the analysis of special bandpass or band-reject filters, which require an extremely narrow pass or reject band. The design aid can be programmed to characterize any filter configuration with a minimum of time and effort and will be used to validate computer-generated data which characterize a particular filter design.

In cooperation with Advanced Modular Concepts Division, Microelectronics Division developed two computer programs to compute the scaling coefficients essential in implementing a given filter design. One program utilizes the bilinear z-transform method and was chosen because it optimizes sine wave inputs, yields complex filter structures, and provides an output which retains the best characteristics of gain magnitude and frequency response. The other program utilizes the direct design approach. It uses the Fletcher-Powell optimization algorithm, yielding a complex filter structure, and does not require transformation of an analog design to obtain the desired coefficients.

Detailed documentation of the work accomplished during FY73—including results, recommendations for future efforts, and theory and design information—is contained in a technical note now being prepared.

The need to develop signal processing capability utilizing digital filters is most important in meeting the future requirements of modern communication systems. Signal transmission and recovery techniques are becoming more complex, and reliability and accuracy requirements more demanding. In many cases, the accuracy and stability required by these systems can be greatly enhanced through the proper application of digital filters.

ZF61.512
(NELC Z263)

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Adaptive Array Antenna

The objective of this task is to develop techniques for an antenna array which can adapt to the nonconstant electromagnetic environment in which it must operate. An important characteristic of the adaptive array is its ability to operate in a multijammer environment, and adaptive arrays can be used to reduce or eliminate effects of clutter, undesired scatterers, rf interference, and other noise sources that are spatially or spectrally distinct from the signal.

The designers of conventional antennas and arrays usually attempt to counter environmental problems with low antenna sidelobes. There are, however, practical and theoretical limitations on the achievable sidelobe level, which is on the order of -30 dB. The adaptive array tends to overcome these limitations by placing radiation pattern nulls or reduced sidelobes in the directions of the noise or spurious signal sources and allowing sidelobes to rise in other directions. Since this is done adaptively by means of feedback loops, the effects of errors in the array are automatically reduced.

The adaptive array has application in communications and EW when undesired signals must be minimized or eliminated. For the active deceptor, the array can be self-focusing and can seek signals and determine angle-of-arrival data.

The adaptive array minimizes undesired signals in communications and EW. The NELC approach adds a beam former along with rf feedback circuits. It provides a transmit function, improves performance, and reduces complexity.

In FY73, an extensive survey of available adaptive array techniques was completed and areas were identified in which further improvements can be made. It was found that presently available adaptive array techniques have several problem areas. One is the inability to resolve and reject noise sources which are at angles near the desired signal direction. In order to improve resolution and the ability to reject noise, larger apertures and increased numbers of elements are required, with the resulting need to decrease complexity and cost per element. The time response of the adaptation cycle also increases with number of elements; hence, methods of reducing reaction time are also needed. Finally, incorporation of a transmit function into an adaptive array is a desirable feature which is not available in present approaches.

The NELC approach to some of these problems is to incorporate hybrid matrix multiple beam former in the adaptive array along with rf feedback circuits. The Butler matrix provides N orthogonal independent beams from an N-element linear array. By adaptively processing the beam outputs rather than the element outputs, several advantages accrue:

1. The four beams may be used singly to provide a transmit function;

2. The multibeam matrix acts as an rf preprocessor which results in improved convergence and time response of the adaptation feedback loops;

3. By combining beam outputs before processing, a reduction in the number of processing channels can be achieved with little sacrifice in array resolution.

Important elements in the design process are determined by computer simulation of the adaptive array parameters. Simulation was used, for example, to demonstrate the improvement in performance gained by using the hybrid matrix beam former and to determine effects on patterns of obstacles in the radiated field. Selection of a final hardware configuration will be made by including the various parameters in the simulation program and adjusting them to obtain the best performance from low-cost available components.

Computer simulation experiments are being continued. During FY74, preliminary hardware tests will be undertaken, and a final hardware configuration determined. Future plans call for a working demonstration model to be completed and tested near the end of FY75.

PUBLICATION

Provencher, J. H., "Adaptive Array Antenna Study," NELC Technical Note 2301, 27 February 1973

2X61.112
(NELC 2264)

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225-7098

Time and Frequency Domain Reflectometry

NAVSHIPS letter ser 094 of 27 November 1970 stressed the need of providing every Naval vessel with portable instrumentation capable of detecting and locating faults in rf coaxial and waveguide transmission lines. The problem was approached in two phases:

Phase I

1. Survey of the feasibility of TDR/FDR techniques, technology, and state-of-the-art equipments.
2. In-house, field, and laboratory survey and evaluation of selected candidate TDR/FDR procedures.

Phase II

1. Design and fabrication of a breadboard prototype instrument or modification of an existing commercial system.
2. Evaluation of the prototype system aboard fleet vessels.
3. Provision of military documentation and specifications for system procurement.

PROGRESS IN FY73

The survey conducted during Phase I indicated that three TDR/FDR techniques were available as candidate approaches. These included pulse, frequency modulation, and swept frequency techniques. The first two are currently available on the commercial market. The swept frequency technique, an approach developed by the CSIRO Division of Applied Physics, National Standards Laboratory, Sydney, Australia, has not been developed commercially.

The pulse and FM techniques have the disadvantages of lacking bandwidth, portability, and resolution. The swept frequency technique has apparently overcome these shortcomings.

The major goal for Phase II in FY73 was to procure both the pulse and FM systems and to fabricate a breadboard swept frequency system. The systems would then be compared and evaluated with the most likely candidate being selected for further modification or development as a prototype system. The pulse system was procured and a breadboard swept frequency system has been fabricated. The FM system has not been procured due to lack of availability, as this is currently a one-of-a-kind instrument.

PLANS FOR FY74

It is expected that the FM system will be procured early in FY74. The three approaches will then be compared and the development of a prototype system pursued.

2F61.512
(NELC 2265)

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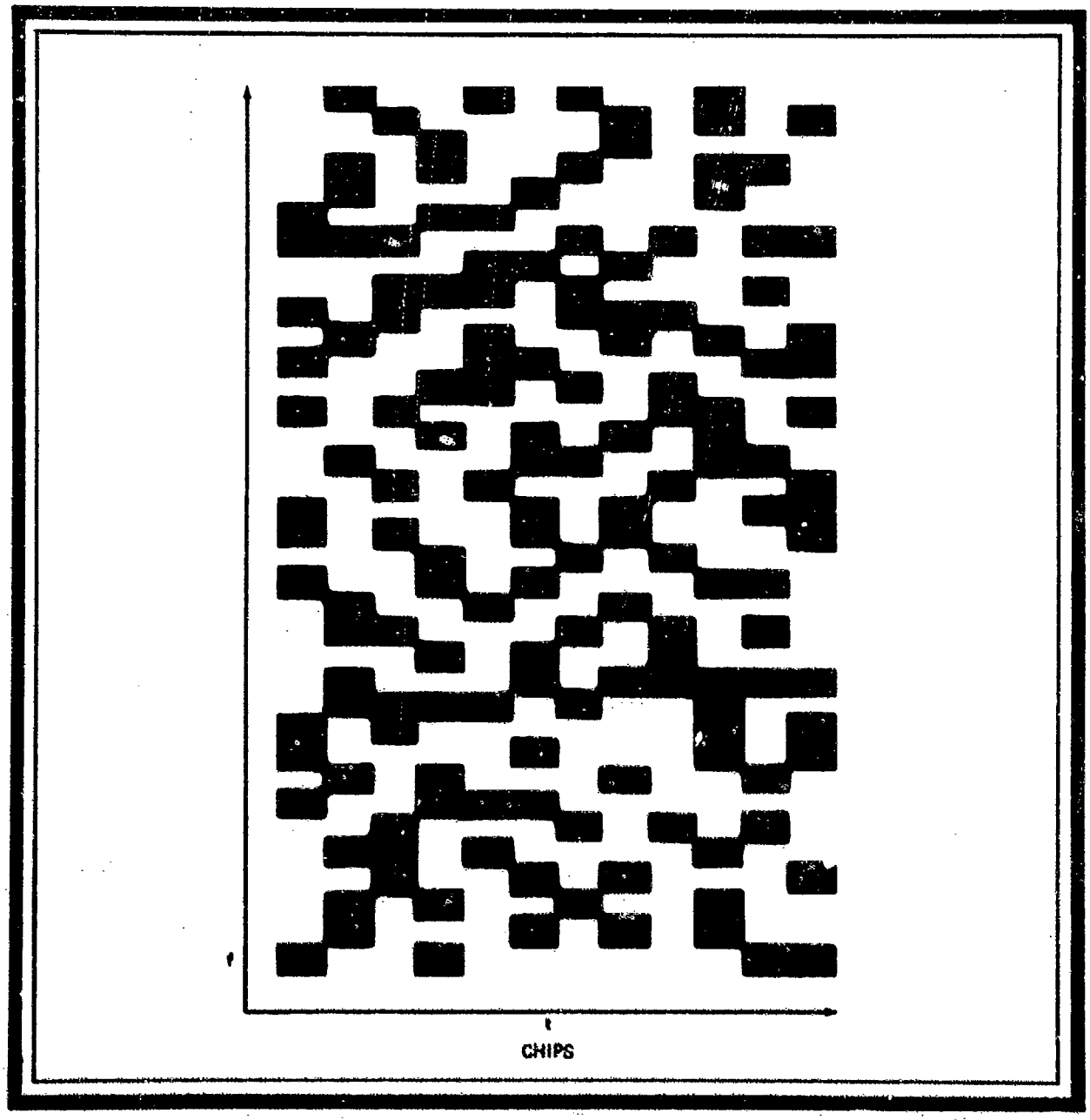
225-7095

Signal and Information Processing



Schalkwijk Source Coding

The work accomplished from 1 July 1972 through 30 June 1973 was concerned with the Schalkwijk algorithm for data compression. This algorithm was simulated on the IBM 360 computer. Pictorial data sources were converted to magnetic tape, which was then used as input to the encoding program. The encoded data were then used as input to the decoding program. The output data were converted from magnetic tape to hard-copy picture and compared with the input picture. Compression ratios were automatically computed by the computer programs.

Another set of programs was written and debugged which allowed the data to be degraded in a controlled manner. This made possible even greater data compression ratios. The output pictures were compared with the input to determine what degree of degradation was subjectively tolerable.

The follow-on work resulting from this problem is the actual hardware construction of the data compression device. This is being carried on at the present time.

PUBLICATIONS

Lawrence, J. C., "Application of Schalkwijk Source Coding Techniques to Pictorial Sources," NELC Technical Report 1867, 12 March 1973

ZR014.08
(NELC Z179)

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225-6266

Universal, Modularized Digital Controller for Analog Power Drives Aboard Ship

Frequently, in Navy applications, analog power drives must be controlled by position orders generated by a centralized (or master) digital computer. The effort under problem Z239 has been directed towards developing a modularized digital controller (minicontroller) which serves as both an interfacing device and a dynamic compensator in a closed-loop digital control configuration. This device is capable of controlling a broad class of analog power drives including gun mounts, tracking antennas, missile launchers, and similar electrical and electrohydraulic systems.

The development of the minicontroller was initiated in FY71. During this year, the specific functions that were to be performed were defined and the controller was logically grouped into modules. The minicontroller incorporates four basic modules. Three of the modules are identical for all applicable systems, and the fourth is, in general, unique for each system.

During FY72 the minicontroller evolved from basic breadboard to a "brassboard" prototype. The breadboard was constructed exclusively with P-channel enhancement MOS devices. The brassboard used complementary MOS (CMOS) devices in place of some of the PMOS devices.

Extensive testing was performed during this time. In-house tests included checkout in the NELC hybrid simulation laboratory and on the 3"/50 gun test facility. In February 1972, successful operational tests were conducted using the MK 112 ASROC launcher located at Naval Underwater Systems Center, Newport, Rhode Island.

The minicontroller has been expanded to include a built-in function generator that provides "canned" input commands during the self-test mode of operation. The minicontroller has also been slightly modified to control up to four axes of rotation and would typically be used to control one 3-axis system or two 2-axis systems.

The "minicontroller" (less than ½ ft^3) developed by NELC is "universal" in that it controls gun mounts, tracking antennas, missile launchers, and other electrical and electrohydraulic analog power drives. It now handles up to four axes of rotation and has a built-in function generator for self-test.

The four basic minicontroller modules have been partitioned into printed-circuit cards. The art work and layout of the cards have been completed, and the boards are being fabricated. The production model of the minicontroller is being built with these cards and contains all CMOS devices.

Further testing has demonstrated the broad area of applicability of the minicontroller. In November 1972, successful tests were performed on a Mk 42 Mod 9 gun mount located at the Naval Weapons Laboratory, Dahlgren, Virginia.

FOLLOW-ON AND RELATED TASKS

The tests at NWL were performed to determine the feasibility of utilizing the minicontroller in the proposed upgated Mk 68 Gun Fire Control System. The results fully demonstrated the feasibility of such a utilization, and two fully documented production model controllers are scheduled to be delivered to NWL during the first quarter of FY74.

The minicontroller is also being used to control a miniature three-axis K_a band satellite communication antenna under development at NELC.

ZF61.512
(NELC Z239)

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225-6257

Speech Processing for Radio Communications

An unmodified speech waveform makes inefficient use of the capabilities of a voice radio transmitter. Because of the wide dynamic range of speech, when voice peaks drive the transmitter to full output, some consonant sounds are as much as 30 dB weaker and may be lost in noise. Proper speech processing to compress dynamic range and emphasize the most important frequencies of the voice spectrum can improve intelligibility under marginal link conditions by the equivalent of at least a tenfold increase in transmitter power. Nevertheless, most equipment in use by the armed services provides no processing at all or at best takes less than full advantage of the techniques available. Improvements in audio design appear only slowly, as new equipments come into use. What is needed is an inexpensive universal processor with which existing transmitters can be retrofitted with a minimum of difficulty. This problem is intended to provide a firm experimental basis for the development of such a unit.

Voice transmissions need processing if they are to be received "loud and clear" under marginal conditions. Most existing systems do not provide it. This program supports the development of a universal processor for easy retrofit of existing transmitters.

The first kind of processing to be evaluated was infinite clipping of the audio signal. The result is speech of high intelligibility and greatly reduced dynamic range but the quality is harsh and mushy, unpleasant to listen to. Reasonable quality is required for a universal processor because of the need for user acceptance. A novel circuit was then developed for a syllabic compressor to remove most of the fluctuation in amplitude from syllable to syllable, including provision for inhibiting gain recovery during pauses to eliminate the annoying effect found in conventional compressors in which noise rises to fill the pause. This unit gave output of excellent quality but was a bit complex for some applications, using a total of 18 linear integrated circuits. Another processor was developed using conventional automatic gain control to hold overall level constant, followed by 15 dB of peak clipping to reduce amplitude of the stronger vowels. This unit was simpler, using only six integrated circuits, yet proved to be slightly superior to the compressor in preliminary tests.

A third processor has been designed and will be constructed in early FY74. It translates the speech signal upward in frequency by single-sideband (SSB) modulation, infinitely clips the SSB signal, and demodulates it back to audio. This technique compresses dynamic range very effectively and greatly reduces the distortion normally generated by infinite clipping, because all the harmonics and many of the intermodulation products produced by clipping are remote in frequency from the SSB signal and are easily removed by filtering. The circuit includes provision for suppressing noise during pauses and handles speech inputs of widely varying level in the presence of a wide range of noise levels. Intelligibility tests using word lists under a variety of simulated link conditions will permit a quantitative relative evaluation of the three processors.

The work accomplished on the problem so far has resulted in an informal recommendation to NAVSEC for improvements in the 5MC Flight Deck Announcing System and recommendations to NELC Surface Systems Program Office for speech processing circuitry in the Man-on-the-Move Communications System being developed by NELC.

PUBLICATIONS

Allen, C. R., "Low-Drift Integrator Circuit," *IEEE Journal of Solid-State Circuits*, vol SC-8, no 3, 236-237 (June 1973)

A member of the Board of Editors of the *Journal of the Audio Engineering Society* has invited submission of a paper on the syllabic compressor. The paper will be written early in FY1974.

ZF61.212
(NELC Z258)

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225-7372

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Hall, D. B., and Yeh, C., "Leaky Waves in a Heteroepitaxial Film," *Journal of Applied Physics, 44,* 2271-2274, 1973

Lile, D. L., "Surface Photovoltage and Internal Photoemission at the Anodized InSb Surface," *Surface Science, 34,* 337, 1973

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Schiff, M., and Lagnado, I., "Programmable Coding Techniques for Semiconductor/Acoustic Surface Wave Devices," *Proceedings IEEE 1972 Region Six Conference,* p 96, 1972

White, C. T., "Visual Evoked Response and Patterned Stimuli," a chapter in a forthcoming book edited by A. Riesen, University of California, Riverside, California

White, C. T., "Visual Testing With Evoked Potentials," College of Optometrists in Vision Development; and Proceedings, Annual Meeting of EEG Technologists, Houston, Texas, November 1972

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Wieder, H. H., and Clawson, A. R., "Photo-Electronic Properties of $InAs_{0.07}Sb_{0.93}$ Films," *Thin Solid Films, 15,* 217, 1973

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Martin, F. C., Jr., "Flat Panel Displays—Who Needs One?" *SID Journal,* vol 10, no 2, March/April 1973

In-House Publications

INDEPENDENT RESEARCH

Hall, D. B., "Integrated Optical Circuits," NELC Technical Report 1861, 30 January 1973

Hershel, R., and Kataoka, R., "Optical Analog Biofeedback Control and Learning Devices," NELC Technical Note 2257, 25 January 1973

Kataoka, R. W., "An Amplifier for Visually Evoked Potentials," NELC Technical Note 2360, 25 April 1973

Kataoka, R. W., "A Simple Method of Attaching Electrodes to the Head for EEG Recordings," NELC Technical Note 2280, 5 February 1973

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Kataoka, R. W., and Allen, C. R., "A Pulse Generator for Evoked Potentials," NELC Technical Note 2315, 7 March 1973

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Martin, J. I., White, C. T., Kataoka, R. W., and Stevens, I., "Electroretinograms (ERGs) and Visually Evoked Responses (VERs) in the California Sea Lion (Zalophus Californianus)," NELC Technical Document (in preparation)

Pappert, R. A., "Plane Wave Theory of Prism and Periodic Couplers for Inhomogeneous Anisotropic Slab Waveguides," NELC Technical Note (in preparation)

Pappert, R. A., "Some Comments on Three Layer Waveguide Structures," NELC Technical Note 2259, 8 January 1973

Shellman, C. H., "Determination of D-Region Electron-Density Distributions from Radio Propagation Data," NELC Technical Report 1856, 23 January 1973

Snyder, F. P., "A Program for Computing Mode Constants for an Isotropic Planar Optical Waveguide," NELC Technical Note (in preparation)

"An EOG Amplifier," NELC Technical Note (in preparation)

"Optical Properties of New Phosphor Materials–$LiYF_4:Pr^{3+}$," NELC Technical Note (in preparation)

"Spectral Emission Properties of Phosphors Under Cathode-Ray Excitation," NELC interim report 2640-1, January 1973

INDEPENDENT EXPLORATORY DEVELOPMENT

Foutz, J., "Selection, Procurement, and Application of Switching Voltage Regulators in Electronic Equipment," NELC Technical Note (in preparation)

Lebduska, R. L., "Fiber Optic Cable Test Evaluation," NELC Technical Report 1869, May 1973

Lebduska, R., and Holma, G., "Fiber Optic Cable Connector Test Evaluation," NELC Technical Note 2367, May 1973

Monahan, M., "Liquid Crystal Devices," NELC Technical Note (in preparation)

Provencher, J. H., "Adaptive Array Antenna Study," NELC Technical Note 2301, 27 February 1973

Schiff, M. L., and Dilley, D. M., "Surface Acoustic Wave Spread Spectrum Modem," NELC Technical Document 248, 18 April 1973

Strand, T., and Persons, C. E., "An Optical Incoherent Correlator for Active Sonar," NELC Technical Report (in preparation)

Symanski, J. J., "Advanced Memory Technologies: A Progress Report," NELC Technical Report 1876, 31 May 1973

Invited Presentations at Professional Meetings

INDEPENDENT RESEARCH

Hershel, R., and Kataoka, R.
"Optical Analog Biofeedback Control and Learning Devices," Conference on Electronic Prosthetics, Lexington, Kentucky, 21-22 September 1972

Martin, J. I., and/or White, C. T.
National Science Teachers Association, San Diego, California, 2 December 1972
American Academy of Optometry, New York, N. Y., 17 December 1972
HEAR Conference, Pasadena, California, 15 February 1973
International Conference on Brain Functions, Quebec, Canada, 4 March 1973
New York State Optometric Center, New York, N. Y., 9 March 1973
San Diego Science Fair, San Diego, California, 7 April 1973
Sonoma State Mental Hospital, Sonoma, California, 1 May 1973
San Jose State University, San Jose, California, 3 May 1973
Naval Postgraduate School, Monterey, California, 7 May 1973
School of Optometry, University of California, Berkeley, California, 8 May 1973
(Twenty additional presentations were made through the NELC Speakers Bureau to public schools, private schools, civic organizations, and student science groups.)

Meiners, L. G.
"Bulk-like Films of Bismuth-Antimony Alloy," National Symposium of the American Vacuum Society, Pittsburgh, Pennsylvania, 3-5 October 1973

Shellman, C. H., "Determination of D-Region Electron-Density Distributions from Radio Propagation Data," COSPAR Symposium on Methods of Measurements and Results of Lower Ionosphere Structure, Konstanz, W. Germany, 23-25 May 1973

Small, Dana L.
"Colloquial English in Navy Command Control Systems," Office of Naval Research Conference on Text Processing and Scientific Research, November 1972 (proceedings to be published)
"Natural Language Processing in Computer Systems," American Society of Naval Engineers Annual Conference, April 1973

INDEPENDENT EXPLORATORY DEVELOPMENT

Doherty, D. W., and Wells, E. J., Jr.
"A Universal Modular Digital Controller," Application of Control Theory to Modern Weapons Symposium. Naval Weapons Center, China Lake, California

Foutz, J.
"Power Supplies–Technology Trends and Problems," Navy Laboratories Briefings for Industry, Naval Electronics Laboratory Center, San Diego, California, 8-9 November 1972

Lebduska, R. L.
"Fiber Optic Cable Test Evaluation," Electrooptics Principles and Applications Seminar, Society of Photooptical Instrumentation Engineers, 1 May 1973

Martin, F. C., Jr.
"Flat Panel Displays–Who Needs One?" Society for Information Display (SID) and American Ordnance Association (AOA)

Roth, A.
"CPA Calculator," IEEE Conference on Minicomputers, Honolulu, Hawaii, 2-5 May 1973. The paper appeared in the 1973 IEEE Region Six Conference Proceedings

Patent Activity

Independent Research

PATENT APPLICATIONS FILED

H. E. Rast and H. H. Caspers

Large-Aperture, Narrowband Detectors for Optical Communication Systems

Narrowband self-filtering optical detector for communication using resonance absorption in gases.

Optical communication systems will increase Naval effectiveness through covert communications.

(Navy Case No. 56,124) Application forwarded 29 June 1973; pending

INVENTION DISCLOSURES SUBMITTED

H. E. Rast and H. H. Caspers

Dye Laser Transmitter-Resonance Fluorescence Detector System for Underwater Optical Communications

The detector is arranged so that the signal is incident at right angles to a stream of molecules of a resonance detector material, such as sodium, and a photodetector or observer is mutually perpendicular to both signal and beam. Use of the detector will improve covert underwater communications.

(Navy Case No. 56,265) Disclosure forwarded to ONR for evaluation

R. F. Potter

Novel Dual-Mode CRT Screen

A dual-phosphor screen consists of a mixture of a phosphor having medium or long persistence emitting in the ultraviolet and a short-persistence green phosphor. The system provides for electronic switching from long-persistence mode to short-persistence mode, and will make possible improved displays for Naval command control.

(Navy Case No. 56,482) Disclosure forwarded to NELC Patent Counsel 12 January 1973

H. E. Rast and H. H. Caspers

Dual-Mode Display Element for Use Under Varying Ambient Illumination

An SiO_2 insulating layer is overlaid on a conducting glass substrate. The layer has a portion removed, and this area is filled in with an electroluminescent phosphor. The phosphor and SiO_2 insulator are overlaid with a thin transparent electrode. A liquid crystal is sandwiched between the above assembly and a conducting glass electrode. Under high ambient light conditions, high contrast and visibility exist by means of the dynamic scattering from the liquid crystal. When ambient illumination diminishes toward darkness, a switch is activated to place the ac potential across the phosphor and produce an illuminated background against which the liquid crystal alphanumeric character may be read in darkness or low ambient light.

The dual-mode element may be used in improved displays for Naval command control.

NELC 2111 Disclosure submitted to NELC Patent Counsel 27 June 1972

Independent Exploratory Development

PATENTS ISSUED

R. L. Dickson, G. B. Johnson, and K. W. Hansen, Jr.
Performance Monitor Unit for Frequency-Multiplexed Hf Modems

Apparatus for monitoring bit error rate of frequency-multiplexed FSK transmissions by transmitting frequency-diversity signals to provide in-band, diversity reception which is used to provide comparative performance measurements of BER between twinned tones or between pairs of twinned tones.

The apparatus can be used to provide frequency management on every ship equipped with the UCC-1 modem and would greatly increase operational effectiveness thereof by significantly decreasing the number of missed messages in the fleet broadcast.

Patent No. 3,706,854 (Navy Case No. 51,423) Serial No. 106,522 Filed 14 January 1971 Issued 19 December 1972

E. J. Schimitschek and J. A. Trias
Method of Preparation of Rare Earth (III) Phosphorus Dichloridates and Phosphorus Dibromidates

A new method of preparation, of particular interest because of its possible use in a liquid laser solution.

Patent No. 3,699,211 (Navy Case No. 52,876) Serial No. 110,920 Filed 29 January 1971 Issued 17 October 1972

PATENT APPLICATIONS FILED

P. L. Writer and M. L. Schiff
Surface Wave Narrow-Bandpass Filter

In bandpass filter feedback loops, surface wave devices comprising aluminum fingers deposited on a piezoelectric substrate are employed to provide transmission characteristics which invert a transmission null into a bandpass. They may be used to provide improved filtering for Naval electronic equipments.

(Navy Case No. 55,701) Pending patent application

L. J. Johnson
Micro-Miniature High-Efficiency Power Supply

A microminiaturized power supply using open-loop voltage regulation with pulse width control. It can be used in all electronic circuits requiring a low-voltage power source.

(Navy Case No. 54,521) Pending Serial No. 312,068 Filed 4 December 1972

R. L. Lebduska
Focusing Coupling Device for Multi-Optical Fiber Cable

A connector for splicing the severed ends of multifiber cables comprising a funnel-shaped tubular section for receiving each cable end. The funnel-shaped tube forces the fibers of each corresponding cable end into a focusing relation with the adjacent cable end. A suitable junction between the cable ends uses an index-matching fluid which permits high light transfer between the cable ends.

Fiber optics cables will have increasing use in Naval communication and data transfer systems.

(Navy Case No. 56,071) Pending Serial No. 373,583 Filed 25 June 1973

AUTHORIZED INVENTION DISCLOSURES

R. L. Lebduska

Fiber Optic Cable Connector

A fiber optic cable connector of identical halves which press-fit together, with the terminals spring loaded to maintain the highly polished cable ends in close contact. A ferrule is provided to maintain the cable ends in perfect alignment and to act as a reservoir for the liquid that may be inserted between the cable ends to enhance optical transmission.

Fiber optics will have increasing use in Naval communication and data transfer systems.

(Navy Case No. 56,390) Authorized for preparation of patent application 22 June 1973

R. L. Lebduska

Fiber Break Detection Methods for Cables Using Multifiber Optical Bundles

A method of assessing the individual fiber breakage in a bundle of fiber glass fibers. The terminated ends are illuminated and viewed through a microscope. The broken fibers appear as black circular elements.

Fiber optics will have increasing use in Naval communication and data transfer systems.

(Navy Case No. 56,533) Authorized for preparation of patent application 13 June 1973

J. J. Symanski and R. H. Ebert

Integrated Parallel-Serial-Parallel Connector

A cable connector including logic circuitry to perform parallel to serial to parallel functions reducing need for multiple parallel data lines.

Use of the connector will improve Naval data transfer systems.

(Navy Case No. 54,948) Authorized for preparation of patent application 15 June 1973

D. N. Williams

Fiber Optic to Electronic Interface

A new interface circuit which will improve Naval communication and data transfer systems.

(Navy Case No. 55,085) Authorized for preparation of patent application 25 July 1973

H. F. Taylor and A. L. Lewis

Optical Coupler

An optical coupler for introducing light signals into an optical data bus and retrieving them. It will improve Naval communication and data transfer systems.

(Navy Case No. 55,909) Authorized for preparation of patent application 7 May 1973

INVENTION DISCLOSURES SUBMITTED

A. Roth and G. M. Holma

Closest-Point-of-Approach Calculator

A manually operated, programmed (dedicated) calculator that computes the range, bearing, and time of closest point of approach of any or all of five selected target ships, and also their course and speed. Its use will be valuable in reducing collisions and casualties.

(Navy Case No. 56,072) Disclosure forwarded to ONR for evaluation 11 January 1973

L. B. Stotts

Tunable On-Off Liquid Crystal Grating Coupler for Fiber Optics

Provides a method for coupling light into fiber optics which will improve Naval communications and data transfer systems.

(Navy Case No. 55,645) Disclosure forwarded to ONR for evaluation 14 September 1972

D. W. Doherty and E. J. Wells, Jr.

Universal Modularized Digital Controller

A miniaturized digital controller for use in a servomechanism system controlled by signal from a computer or other digital data source. It will improve fire control and antenna steering, and also simplify Navy logistics problems.

(Navy Case No. 55,860) Disclosure forwarded for evaluation 14 February 1973

K. Bromley

Correlation Using Charge-Coupled Devices

A system using charge-coupled devices to permit parallel optical correlation and autocorrelation processing in real time. It will improve Naval signal and data processing systems.

(Navy Case No. 56,119) Disclosure forwarded to ONR for evaluation 12 April 1973

L. B. Stotts and W. M. Caton

Birefringence Liquid Crystal Waveguide Coupler

An optical coupler for waveguides employing the birefringence properties of nematic liquid crystals as indiced and controlled by an electric field. It will improve Naval communications and data transfer systems.

(Navy Case No. 56,018) Disclosure forwarded to ONR for evaluation 5 August 1973

L. B. Stotts

Passive Optical Data Bus Coupler Using Cholesteric Liquid Crystals

A passive optical coupler employing the distinctive wavelength sensitivity and polarized directional responsivity of different cholesteric liquid crystal materials to selectively couple out optically transmitted data and information from a common optical bus. Availability of this coupler and other optical components will enable improved data and information transfer systems to be developed for Navy use.

(Navy Case No. 56,703) Disclosure forwarded to ONR for evaluation 11 June 1973

H. K. Landskov

Broadband Antenna

An effective, simple, and inexpensive broadband antenna array for small ships and light vehicles comprising a plurality of like monopoles placed in either triangle or quadrangle configuration with a monopole at each apex. It will make possible an increase in available communications channels with smaller and lighter antennas.

(Navy Case No. 55,647) Disclosure forwarded to ONR for evaluation 1 November 1972

L. J. Johnson

Power Supply

An electronic power supply apparatus for use with a wide range of input voltages. A series switch type regulator is caused to regulate at two voltages (65 and 8 volts). This is done by sensing the regulated voltage and, by means of gate circuits, switching from one mode of regulating to the other without loss of efficiency. This technique enables provision of more efficient and lighter-weight power supplies for Naval electronic systems.

(Navy Case No. 56,508) Disclosure submitted to NELC Patent Counsel 23 March 1973

J. A. Cocci and M. L. Schiff

PCM Synchronization and Multiplexing System

The invention comprises apparatus for obtaining transmitter-receiver synchronization in an audio transceiver which employs pulse code modulation. The apparatus also provides demultiplexing of time-multiplexed signals on the same data channel. The main advantage of the apparatus is that only one frame of data is lost for any one sync error; also, the concept can be implemented reliably and inexpensively by means of conventional digital integrated circuitry.

Benefits to the Navy will be in the form of more accurate less complicated data transfer systems.

(Navy Case No. 56,908) Disclosure submitted to NELC Patent Counsel 7/3/73

Independent Research Projects Terminated in FY73

NELC Problem	Title	DDC Key	Reason for Termination
Z135	Lower Ionospheric Physics (Communications Support)	DN 848016	To be sponsored by DCA (NELC M216) and DNA (NELC M218)
Z162	Guided Wave Optics	DN 112124	To be continued on 61101D ARPA (NELC F215)
Z163	Specialized New Phosphor Materials for Application to Optical Display and Sensor Technology	DN 112125	Phase I completed; TN issued. Funding for further work preempted
Z164	A Tunable Spin-Flip Raman Laser	DN 112126	Incorporated in new project ZR011.07 (NELC Z193)
Z165	Compatible MOS/LSI and Surface Wave Technologies	DN 213056	Feasibility demonstrated
Z166	Natural Language Development	DN 213057	Funding preempted by higher-priority projects
Z167	Diagnosis of Color Anomalies by Means of the Evoked Cortical Potential	DN 213058	To be continued under 61153N RR041.0403 (NELC N528)
Z173	Bioelectronic Study of Marine Mammals	DN 213062	Funding preempted by higher-priority projects
Z176	Surface Barrier Physics and Charge-Coupled Device Applications	DN 213140	Terminated; lack of funding
Z177	Magnetospheric Instability Investigations	DN 213211	Funding preempted
Z178	Narrowband Optical Detectors	DN213182	Incorporated in new project ZR011.07 (NELC Z198)
Z179	Schalkwijk Algorithm Analysis	DN 213183	Incorporated in new project ZF61.212 (NELC Z268)
Z180	Electrooptic Crystal Storage	DN 213184	Funding preempted
Z181	Research in Biopotential Technology	DN 213185	Funding preempted
Z182	Simultaneous Automatic Recording and Automatic Processing of Echocardiograms and Other Physiological Data	DN 213186	Feasibility established; expect funding by Naval Hospital San Diego in FY75
Z183	Hard Copy Technology Improvements	DN 213187	Funding preempted by higher-priority projects
Z184	Chaff Cloud Investigation	DN 213188	Continuation would duplicate Air Force work
Z185	Feasibility of Photomodulating Shipboard Topside RF Interference Sources	DN 213189	Principle demonstrated; portable device for shipboard use impractical
Z186	Kinetics and Effects of Hydrogen at the $Si-SiO_2$ Interphase	DN 213190	Funding preempted by higher-priority projects
Z187	Optical Waveguide Propagation Theory	DN 213191	Funding preempted
Z188	Millimeter Wave Integrated Circuitry for System Applications	DN 213192	Incorporated in new project ZR011.07 (NELC Z193); results to be used in Undersea Warfare Intelligence Support USWIS 63522N S3643 (NELC G224)
Z189	Millimeter Wave Solid-State Circuits	DN 313039	Incorporated in new project ZR011.07 (NELC Z193)
Z190	Pulsed Underwater Optical Sources	DN 313040	To be continued under 62105D ARPA (NELC B403)
Z191	Computer Network Study	DN 313041	65856N X31YY (NELC Q222) will fund this project

Independent Exploratory Development Projects Terminated in FY73

NELC Problem	Title	DDC Key	Reason for Termination
Z238	Command Control Display Module Study	DN 112044	Completed; results to be used in sponsored projects
Z239	Universal, Modularized Digital Controller for Analog Power Drives	DN 112070	Completed. Two production models delivered to NWL for prototype evaluation funded by O&MN(NELC N441). Minicontroller used for antenna pedestal control in SURVSATCOM experimental model, 11403N X15-11 (NELC B218)
Z242	Optical Multiplexing (Towed Acoustic Array)	DN 112087	Completed; ready for advanced funding
Z247	Development of Improved Display Techniques for Advanced Shipboard Display Systems	DN 213046	Completed
Z250	Incoherent Optical Correlator for Active Sonar	DN 213049	Ready for advanced development when CCD components become available
Z251	Advanced Integrated Materials Power Supply	DN 213141	Funding by ONR expected
Z252	Liquid Crystal Devices	DN 213142	Waiting for improved liquid crystal materials
Z253	Small Ship Electronics Systems	DN 213143	Incorporated in new project ZF61.212 (NELC Z270)
Z254	Tuned HF Antenna System for Small High-Speed Ships	DN213193	Completed; ready for 6.3 funding
Z255	Charge-Coupled Device (CCD) Bulk Storage Memory	DN 213194	Incorporated in new project ZR021.02 (NELC Z196)
Z256	Hardwired Information Exchange System	DN 213195	Terminated fall 1972 when incorporated in the Direct Laboratory Funding project
Z257	Transform Source Encoding Techniques for Bandwidth Reduction in Digital Image Transmission	DN 213196	Incorporated in new project ZF61.212 (NELC Z268)
Z258	Speech Processing for Radio Communications	DN 213197	Incorporated in new project ZF61.212 (NELC Z268)
Z259	At-Sea Command Control Systems Study	DN 213198	Completed
Z260	Switching Regulator Technology	DN 213199	Funding preempted by higher-priority projects; results promising
Z261	Fiber Optics Emitter/Detector Evaluation	DN 213200	To be funded by Fiber Optics Technology Development Program 62755N XF54.545.022
Z262	Evaluation and Development of CMOS Technology	DN 213201	To be funded under MEECN 33131N X32-97(NELC B216)
Z263	LSI Digital Filter Development	DN 213202	Feasibility demonstrated; results employed in Direct laboratory Funding project
Z264	Adaptive Array Antenna Development	DN 213203	Continued under 62751N SF12.141.702 (NELC D210)
Z265	Time and Frequency Domain Reflectometry Techniques	DN 213204	Ready for advanced development or industry; NAVSEC Norfolk has started work on it
Z266	Solid-State Oscilloscope/Analyzer for Fleet Electronics Support	DN 213205	Terminated January 1973; approach not innovative
Z267	Fiber Optics Engineering	DN 313042	Completed; report issued. Work continuing on 62703 ARPA (NELC T304)

Active Independent Research Projects for FY73

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	Research Requirement	FY73 Funding $k	DDC Key
Z135	Lower Ionospheric Physics (Communications Support)	C. H. Shellman	933-7677	2200	ZR021.01	65	DN 848016
Z162	Guided Wave Optics	Dr. D. B. Hall	933-6641	2500	ZR011.12	20	DN 112124
Z163	Specialized New Phosphor Materials for Application to Optical Display and Sensor Technology	Dr. H. H. Caspers	933-6591	2600	ZR011.02	65	DN 112125
Z164	A Tunable Spin-Flip Raman Laser Transmitter for Overt/Covert Communication Systems	Dr. S. A. Miller	933-6591	2600	ZR011.07	75	DN 112126
Z165	Compatible MOS/LSI and Surface Wave Technologies	Dr. I. Lagnado	933-6878	4800	ZR021.02	56	DN 213056
Z166	Natural Language Development	Dana L. Small	933-7282	5200	ZR014.10	31.5	DN 213057
Z167	Diagnosis of Color Anomalies by Means of the Evoked Cortical Potential	Dr. J. I. Martin	933-6677	3400	ZR041.01	30	DN 213058
Z173	Bioelectronic Study of Marine Mammals	Dr. C. T. White	933-6677	3400	ZR041.01	25	DN 213062
Z175	Infrared Photocathodes for Navy Detection Systems	Dr. C. R. Zeisse	933-6591	2600	ZR021.03	25	DN 213139
Z176	Surface Barrier Physics and Charge-Coupled Device Applications	H. H. Wieder	933-6591	2600	ZR011.02	35	DN 213140
Z177	Magnetosphere Instability Investigations	Dr. I. J. Rothmuller	933-6822	2200	ZR021.01	50	DN 213211
Z178	Narrowband Optical Detectors	Dr. S. A. Miller	933-6591	2600	ZR021.03	10	DN 213182
Z179	Schalkwijk Algorithm Analysis	J. C. Lawrence	933-6266	2400	ZR014.08	55	DN 213183
Z180	Electrooptical Crystal Storage	Dr. H. F. Taylor	933-7826	2500	ZR011.02	20	DN 213184
Z181	Research in Biopotential Technology	Dr. C. T. White	933-6677	3400	ZR041.01	40	DN 213185
Z182	Simultaneous Automatic Recording and Automatic Processing of Echocardiograms and Other Physiological Data	C. A. Romick	933-6267	3300	ZR041.20	40	DN 213186
Z183	Hard Copy Technology Improvements	G. F. Chandler	933-6762	3100	ZR021.03	45	DN 213187
Z184	Chaff Cloud Investigation	M. Katzman	933-7095	2300	ZR021.05	30	DN 213188
Z185	Feasibility of Photomodulating Topside RFI Sources	G. C. Salisbury	933-7701	2100	ZR011.07	21	DN 213189
Z186	Kinetics and Effects of Hydrogen at the Si-SiO_2 Interphase	Dr. S. J. Szpak	933-6591	2600	ZR011.02	35	DN 213190
Z187	Optical Waveguide Propagation Theory	Dr. R. A. Pappert	933-7688	2200	ZR011.12	35	DN 213191
Z188	Millimeter Wave Integrated Circuitry for System Applications	D. L. Saul	933-6649	2300	ZR021.03	44	DN 213192
Z189	Millimeter Wave Solid-State Circuits	D. Rubin	933-7097	2300	ZR021.03	25	DN 313039
Z190	Pulsed Underwater Optical Sources	Dr. M. Geller	933-7975	2600	ZR011.07	17	DN 313040
Z191	Computer Network Study	M. A. Lamendola	933-7282	5200	ZR014.08	13.5	DN 313041

Active Independent Exploratory Development Projects for FY73

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	ED Task Area	FY73 Funding $k	DDC Key
Z238	Command Control Display Module Study Universal Modularized Digital	A. D. Gomez	933-6541	3100	ZF61.212	40	DN 112044
Z239	Universal Modularized Digital Controller for Analog Power Drives	D. W. Doherty	933-6257	3300	ZF61.512	35	DN 112070
Z242	Optical Multiplexing	Dr. D. J. Albares	933-6641	2500	ZF61.212	38	DN 112087
Z247	Development of Improved Display Techniques for Advanced Shipboard Display Systems	A. D. Gomez	933-6541	3100	ZF61.212	62	DN 213046
Z250	Incoherent Optical Correlator for Active Sonar	K. Bromley	933-6641	2500	ZF61.112	44	DN 213049
Z251	Advanced Integrated Material Power Supplies	L. J. Johnson	933-6878	4800	ZF61.512	60	DN 213141
Z252	Liquid Crystal Devices	M. A. Monahan	933-6641	2500	ZF61.212	70	DN 213142
Z253	Small-Ship Electronic Systems	A. Roth	933-6859	4300	ZF61.212	(44.6*)	DN 213143
Z254	Tuned HF Antenna System for Small High-Speed Ships	C. A. Nelson	933-7336	2100	ZF61.512	65	DN 213193
Z255	Charge-Coupled Device (CCD) Bulk Storage Memory	J. J. Symanski	933-6516	3200	ZF61.212	44	DN 213194
Z256	Hardwired Information Exchange System	Dr. D. W. Gage	933-6616	3200	ZF61.212	8.9	DN 213195
Z257	Transform Source Encoding Techniques for Bandwidth Reduction in Digital Image Transmission	D. C. McCall	933-6257	3300	ZF61.112	50	DN 213196
Z258	Speech Processing for Radio Communications	C. R. Allen	933-7372	3400	ZF61.212	37	DN 213197
Z259	At-Sea Tactical Command Control System	G. E. Ereckson	933-2208	200	ZF61.212	65	DN 213198
Z260	Switching Regulator Technology for Small-Ship Electronics	J. Foutz	933-6877	4800	ZF61.512	57	DN 213199
Z261	Fiber Optics Emitter/Detector Evaluation	Dr. S. A. Miller	933-6691	2600	ZF61.212	70	DN 213200
Z262	Evaluation and Development of CMOS Technology	Dr. I. Lagnado	933-6878	4800	ZF61.512	45	DN 213201
Z263	LSI Digital Filter Development	C. A. West	933-7023	4800	ZF61.512	50	DN 213202
Z264	Adaptive Array Antenna Development	J. H. Provencher	933-7098	2300	ZF61.112	30	DN 213203
Z265	Time and Frequency Domain Reflectometry Techniques	J. E. Boyne	933-7095	2300	ZF61.512	56.5	DN 213204
Z266	Solid-State Oscilloscope/Analyzer for Fleet Electronics Support	J. W. Troy	933-7232	2400	ZF61.512	13.9	DN 213205
Z267	Fiber Optics Engineering	R. L. Lebduska	933-7296	4400	ZF61.212	30	DN 313042

*FY72 carryover only

Independent Research Projects for FY74

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	Research Requirement	FY74 Funding $k	DDC Key
Z175	Low Light TV IR Cathode	Dr. C. R. Zeisse	933-6591	2600	ZR021.03	45	DN 213139
Z192	Equatorial Scintillation Studies for Improved SATCOM	R. U. Hopkins	933-7767	2400	ZR021.01	55	New
Z193	Devices for New Frequency Regions	J. W. Carson	933-6763	2300	ZR011.07	245	New
Z194	CCD Signal Processing Imager	Dr. I. Lagnado	933-6877	4800	ZR021.03	50	New
Z195	Solid-State Materials and Processes Characteristics	C. E. Holland, Jr.	933-6860	4020	ZR011.02	250	New
Z196	Solid-State Mass Memories	J. J. Symanski	933-6515	3200	ZR021.03	120	New
Z197	Programmable Electrooptical Processor	K. Bromley	933-6641	2500	ZR011.12	75	New
Z198	Narrowband Underwater Laser and Detector	Dr. E. J. Schimitschek	933-7975	2500	ZR011.07	90	New

Independent Exploratory Development Projects for FY74

NELC Problem	Title	Principal Investigator	AUTOVON	NELC Mail Code	ED Task Area	FY74 Funding $k	DDC Key
Z268	Voice and Image Data Companding	Dr. D. O. Christy	933-6515	3200	ZF61.212	300	New
Z269	TELCAM (Telecommunication Equipment Low Cost Acquisition Method)	M. V. Eddy	933-6525	4400	ZF61.512	250	New
Z270	SSCCS (Small Ship Command Control System)	D. G. Mudd	933-6258	3300	ZF61.212	475	New
Z271	IISAR and AD (Integrated Information Storage and Retrieval and Animated Display)	H. F. Wong	933-7739	3200	ZF61.212	75	New

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13 ABSTRACT

This document is an overview of the NELC IR & IED programs. It summarizes the accomplishments achieved within each project in FY73. Longer articles are presented on four of the most significant projects—lower ionospheric physics, natural language development, small ship electronics systems—CPA calculator, and transform source encoding techniques for bandwidth reduction in digital image transmission.

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